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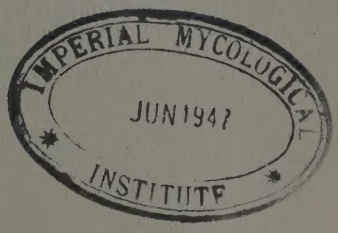

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MATHÉMATIQUES

REMARQUES SUR L'ÉTUDE DES APPROXIMATIONS AU MOYEN DES FONCTIONS RATIONNELLES DANS LE DOMAINE COMPLEXE

Par A. L. SCHAGINJAN

(Présenté par S. L. Soboleff, de l'Académie, le 26. I. 1944)

1. S. N. Bernstein a démontré (1) que si $f(x)$ est une fonction de x continue sur l'axe réel et vérifiant la condition

$$\lim_{|x|\to\infty} f(x)\,e^{-|x|}=0$$

alors l'approximation au moyen de polynômes $\{P_n(x)\}$ sur tout l'axe ox est possible au sens suivant

$$\sup e^{-|x|}\,|f(x)-P_n(x)|\to 0 \text{ pour } n\to\infty$$

et on peut indiquer une fonction $f(x)$ pour laquelle l'approximation

$$\sup e^{-|x|^{1-\varepsilon}}\,|f(x)-P_n(x)|\to 0 \quad (n\to\infty,\ \varepsilon>0)$$

est impossible.

Dans le cas d'approximation sur le demi-axe la fonction de poids $e^{-|x|}$ doit être remplacée par la fonction $e^{-|x|^{1/2}}$.

2. Dans la présente Note nous étendons ce résultat de S. N. Bernstein au cas de l'approximation des fonctions analytiques dans certaines classes de domaines non bornés d'une variable complexe.

Nous appliquons les résultats obtenus à l'étude des approximations au moyen de fonctions rationnelles ayant des pôles sur la frontière du domaine, ainsi qu'à l'étude des problèmes de l'approximation des fonctions continues arbitraires dans certaines classes d'ensembles partout non denses et non bornés. Ces résultats présentent des généralisations d'un résultat connu de M. A. Lavrentieff (2).

3. Théorème 1. *Soit D, un domaine arbitraire simplement connexe, situé à l'intérieur de la bande $|\operatorname{Im} z|\leqslant a$ et topologiquement équivalent à lui. Si $f(x)$ est régulier à l'intérieur de D, continue dans D et sur sa frontière et vérifie la condition*

$$\lim_{|z|\to\infty} f(z)\,e^{-|z|}=0$$

alors elle admet une approximation au moyen de polynômes $\{P_n(z)\}$ telle que

$$\sup e^{-|z|^{1+\varepsilon}}\,|f(z)-P_n(z)|\to 0 \quad (n\to\infty)$$

$\varepsilon>0$ étant quelconque. D'ailleurs, il existe des fonctions, par exemple $\frac{1}{\sqrt{z-2ai}}$, pour lesquelles l'approximation

$$\sup e^{-|z|^{1-\varepsilon}}\left|\frac{1}{\sqrt{z-2ai}}-P_n(z)\right|\to 0 \quad (n\to\infty,\ \varepsilon>0)$$

est impossible dans une bande.

Théorème 2. *Si D_2 est un domaine arbitraire simplement connexe, situé à l'intérieur d'une certaine parabole $y^2=2px$ et son ensemble complémentaire par rapport au plan entier est un domaine simplement connexe, alors pour chaque $f(z)$ régulière à l'intérieur de D_2, continue dans le domaine fermé et vérifiant la condition*

$$\lim_{|z|\to\infty} f(z)\, e^{-|z|^{1/2}} = 0$$

l'approximation par polynômes au sens

$$\sup e^{-|z|^{1/2+\varepsilon}} |f(z) - P_n(z)| \to 0 \text{ pour } n\to\infty,\ z \subset D_2,$$

($\varepsilon > 0$ *quelconque*) *est possible. D'ailleurs, il existe des fonctions, par exemple* $\frac{1}{1+z}$, *pour lesquelles l'aproximation*

$$\sup e^{-|z|^{1/2-\varepsilon}} \left| \frac{1}{1+z} - P_n(z) \right| \to 0 \text{ pour } n\to\infty$$

est impossible à l'intérieur de la parabole $y^2=2px$.

Théorème 3. *Soit D_3 un domaine simplement connexe, situé dans l'angle $-\alpha \leqslant \arg z \leqslant \alpha$, $\alpha < \pi$, et tel que $t=\frac{1}{1+z}$ le transforme en un domaine fini dont le complémentaire par rapport au plan entier est connexe; alors pour chaque $f(z)$, régulière à l'intérieur de $\overline{D}_3$, continue dans ce domaine et sur sa frontière et vérifiant la condition*

$$\lim_{|z|\to\infty} f(z)\, e^{-|z|^{\rho}} = 0$$

où $\rho = \frac{\pi}{2\pi-\alpha}$, $\varepsilon > 0$ *quelconque, l'approximation par polynômes* $\{P_n(z)\}$ *au sens*

$$\sup e^{-|z|^{\rho+\varepsilon}} |f(z) - P_n(z)| \to 0,\ \rho = \frac{\pi}{2\pi-\alpha}$$

($\varepsilon > 0$ *quelconque*) *est possible. D'ailleurs, il existe des fonctions, par exemple* $\frac{1}{1+z}$, *pour lesquelles l'approximation*

$$\sup e^{-|z|^{\rho-\varepsilon}} \left| \frac{1}{1+z} - P_n(z) \right| \to 0,\ \rho = \frac{\pi}{2\pi-\alpha}$$

($\varepsilon > 0$ *quelconque*) *est impossible dans* $-\alpha \leqslant \arg z \leqslant \alpha$.

4. M. A. Lavrentieff a démontré (2) que sur chaque ensemble borné, partout non dense et qui ne divise pas le plan une fonction continue quelconque peut être approchée uniformément par polynômes.

Les résultats précédemment indiqués permettent de généraliser ce résultat de M. Lavrentieff.

Théorème 4. *Si Δ_1 est un ensemble quelconque partout non dense dans la bande $|\operatorname{Im} z| \leqslant a$ et tel que la fonction $t=\frac{1}{z-2ai}$ le transforme en un ensemble qui ne divise pas le plan, alors pour chaque $f(z)$, continue sur Δ_1 et vérifiant la condition*

$$\lim_{|z|\to\infty} f(z)\, e^{-|z|} = 0$$

l'approximation au sens

$$\sup e^{-|z|^{1+\varepsilon}} |f(z) - P_n(z)| \to 0,\ n\to\infty,$$

($\varepsilon > 0$ *quelconque*) *est possible; et il existe des fonctions, par exemple* $\frac{1}{z-2ai}$, *pour lesquelles l'approximation*

$$\sup e^{-|z|^{1/2-\varepsilon}} \left| \frac{1}{z-2ai} - P_n(z) \right| \to \infty,\ n\to\infty$$

($\varepsilon > 0$ *quelconque*) *est impossible, au moins sur l'axe réel.*

Théorème 5. *Si Δ_2 est un ensemble non-borné, partout non dense à l'intérieur d'une certaine parabole $y^2 = 2px$ et Δ_2 ne morcelle pas le plan, alors pour chaque $f(z)$, continue sur Δ_2 et vérifiant la condition*

$$\lim_{|z|\to\infty} f(z)\, e^{-|z|^{1/2}} = 0$$

l'approximation au sens

$$\sup e^{-|z|^{1+\varepsilon}} |f(z) - P_n(z)| \to 0, \quad n \to \infty$$

($\varepsilon > 0$ quelconque) est possible; et il existe des fonctions, pour lesquelles l'approximation

$$\sup e^{-|z|^{1-\varepsilon}} |f(z) - P_n(z)| \to 0$$

($\varepsilon > 0$ quelconque) est impossible, par exemple, sur la parabole $y^2 = 2px$.

Théorème 6. *Si Δ_3 est un ensemble non-borné, partout non dense, contenu dans l'angle $-\alpha/2 \leqslant \arg z \leqslant \alpha/2$ et Δ_3 ne morcelle pas le plan, alors pour chaque $f(z)$, continue sur Δ_3 et vérifiant la condition*

$$\lim_{|z|\to\infty} f(z)\, e^{-|z|^{\rho}} = 0$$

où $\rho = \frac{\pi}{2\pi - \alpha}$, l'approximation au sens

$$\sup e^{-|z|^{\rho+\varepsilon}} |f(z) - P_n(z)| \to 0$$

pour $\rho = \frac{\pi}{2\pi - \alpha}$ ($\varepsilon > 0$ quelconque) est possible; et il existe des fonctions, par exemple $\frac{1}{1+z}$, pour lesquelles l'approximation au sens

$$\sup e^{-|z|^{\rho-\varepsilon}} |f(z) - P_n(z)| \to 0$$

est impossible sur les côtés de l'angle $\arg z = \pm \alpha/2$.

5. Nous avons démontré ([3],[4]) que la possibilité de l'approximation au moyen de fonctions rationnelles, ayant des poles sur la frontière du domaine, dépend des propriétés métriques du domaine donné.

En vertu de ce qui précède on peut démontrer le théorème suivant.

Théorème 7. *Soit B_1 un domaine borné simplement connexe dont le complémentaire est connexe, qui contient $z = 0$ sur sa frontière, et tel que $t = \frac{1}{z}$ le transforme en un ensemble situé à l'intérieur d'une certaine bande; alors pour chaque $f(z)$, régulière à l'intérieur de B_1, continue dans B_1 et vérifiant la condition*

$$\lim_{|z|\to 0} f(z)\, e^{\frac{1}{|z|}} = 0$$

il est possible d'obtenir une approximation de la forme

$$\sup e^{\frac{1}{|z|^{1+\varepsilon}}} \left| f(z) - Q_n\left(\frac{1}{z}\right) \right| \to 0, \quad n \to \infty$$

où $\varepsilon > 0$ est quelconque et $Q_n\left(\frac{1}{z}\right)$ est un pôlynôme par rapport à $\frac{1}{z}$; et il existe des fonctions, par exemple z, pour lesquelles une approximation de la forme

$$\sup e^{\frac{1}{|z|^{1-\varepsilon}}} \left| z - Q_n\left(\frac{1}{z}\right) \right| \to 0$$

est impossible entre deux circonférences qui sont tangentes au point $z = 0$.

Théorème 8. *Si B_2 est un domaine simplement connexe dont le complémentaire est connexe, qui contient le point $z=0$ sur sa frontière, et tel que $t=\frac{1}{z}$ le transforme en un domaine à l'intérieur d'une certaine parabole du second ordre, alors pour chaque $f(z)$, régulière à l'intérieur de B_2, continue dans le domaine fermé B_2 et vérifiant la condition*

$$\lim_{|z|\to 0} f(z)\, e^{-\frac{1}{|z|^{1/2}}} = 0$$

l'approximation au sens

$$\sup e^{-\frac{1}{|z|^{1/2+\varepsilon}}} \left| f(z) - Q_n\left(\frac{1}{z}\right)\right| \to \infty, \quad z \subset B_2, \quad \varepsilon > 0$$

est possible; et il existe des fonctions, par exemple z, pour lesquelles l'approximation

$$\sup e^{-\frac{1}{|z|^{1-\varepsilon}}} \left| z_n - Q_n\left(\frac{1}{z}\right)\right| \to 0$$

est impossible dans un domaine du même type.

Théorème 9. *Soit B_2 un domaine simplement connexe dont le complémentaire est connexe, qui contient le point $z=0$ sur la frontière et tel que $t=\frac{1}{z}$ le transforme en un certain angle égal à α; alors pour chaque $f(z)$, régulière sur sa frontière et vérifiant la condition*

$$\lim_{|z|\to 0} f(z)\, e^{-\frac{1}{|z|^{\rho}}} = 0$$

où $\rho = \frac{\pi}{2\pi - \alpha}$, l'approximation au sens

$$\sup e^{-\frac{1}{|z|^{\rho+\varepsilon}}} \left| f(z) - Q_n\left(\frac{1}{z}\right)\right| \to 0, \quad \rho = \frac{\pi}{2\pi-\alpha}, \quad \varepsilon > 0$$

est possible; et il existe des fonctions, par exemple z, pour lesquelles l'approximation

$$\sup e^{-\frac{1}{|z|^{\rho-\varepsilon}}} \left| z - Q_n\left(\frac{1}{z}\right)\right| \to 0$$

est impossible à l'intérieur de l'angle $|\arg z| < \alpha/2$.

6. Enfin, il suit de nos résultats et du théorème de M. Lavrentieff qu'on a les théorèmes:

Théorème 10. *Soit S_1 un ensemble borné partout non dense avec un complémentaire connexe, contenant le point $z=0$ et qui est transformé par $t=\frac{1}{z}$ en une bande; alors pour chaque fonction $f(z)$, continue sur S_1 et vérifiant la condition*

$$\lim_{|z|\to 0} f(z)\, e^{-\frac{1}{|z|}} = 0$$

l'approximation

$$\sup e^{-\frac{1}{|z|^{1+\varepsilon}}} |f(z) - P_n(z)| \to 0, \quad \varepsilon > 0$$

est possible; et il existe des fonctions, par exemple z, pour lesquelles l'approximation au sens

$$\sup e^{-\frac{1}{|z|^{1-\varepsilon}}} \left| z - Q_n\left(\frac{1}{z}\right)\right| \to 0$$

est impossible sur les arcs de deux circonférences tangentes au point $z=0$.

Théorème 11. *Soit S_2 un ensemble borné partout non dense avec un complémentaire connexe, contenant le point $z=0$ et tel que $t=\frac{1}{z}$ le transforme en un ensemble à l'intérieur d'une certaine parabole du second ordre; alors pour chaque $f(z)$, continue sur S_2 et vérifiant la condition*

$$\lim_{|z|\to 0} f(z)\, e^{-\frac{1}{|z|^{1/2}}} = 0$$

l'approximation au sens

$$\sup e^{-\frac{1}{|z|^{1/2+\varepsilon}}} \left| f(z) - Q_n\left(\frac{1}{z}\right) \right| \to 0$$

est possible; et il existe des fonctions, par exemple z, pour lesquelles l'approximation

$$\sup e^{-\frac{1}{|z|^{1/2-\varepsilon}}} \left| z - Q_n\left(\frac{1}{z}\right) \right| \to 0,\ z \subset B_2$$

($\varepsilon > 0$) est impossible dans un certain ensemble du même type.

Théorème 12. *Soit S_3 un ensemble parfait, borné, partout non dense avec un complémentaire connexe, contenant le point $z=0$ et tel que $t=\frac{1}{z}$ le transforme en un ensemble intérieur à un certain angle égal à α. Alors pour chaque $f(z)$, continue sur S_3 et vérifiant la condition*

$$\lim_{|z|\to 0} f(z)\, e^{-\frac{1}{|z|^{\rho}}} = 0$$

où $\rho = \frac{\pi}{2\pi - \alpha}$, l'approximation au sens

$$\sup e^{-\frac{1}{|z|^{\rho+\varepsilon}}} \left| f(z) - Q_n\left(\frac{1}{z}\right) \right| \to 0,\ z \subset S_3,\ \rho = \frac{\pi}{2\pi - \alpha}$$

($\varepsilon > 0$ quelconque) est possible; et il existe des fonctions, par exemple z, pour lesquelles l'approximation

$$\sup e^{-\frac{1}{|z|^{\rho-\varepsilon}}} \left| z - Q_n\left(\frac{1}{z}\right) \right| \to 0$$

est impossible sur les côtés de l'angle $\arg z = \pm \alpha/2$, $|z| < 1$.

7. Indiquons la méthode de la démonstration des théorèmes cités. Pour démontrer les théorèmes 1—3 nous interpolons certaines fonctions très simples dans des domaines finis déterminés, et évaluons les polynômes interpolatoires dans les parties restantes des domaines donnés.

Tous les autres résultats suivent directement des théorèmes 1—3. Pour démontrer les résultats négatifs nous appliquons la méthode qui est indiquée dans nos Notes ([3], [4]).

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Erevan.

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ASTRONOMY

SYSTEMATIC MOTIONS IN THE ATMOSPHERES OF CERTAIN WHITE SUPERGIANTS

By G. A. SHAJN, Member of the Academy

1. The absence of noticeable differences in the radial velocities for different atoms in spectra of usual stars is a testimony of the absence of systematic motions of gases, of absence of stratification in distribution of the atoms, and probably also of low depth of the reversing layer. Things are different for stars with extended atmospheres, where stratification and systematic motions appear to be more probable. In extended atmospheres one rather can expect the existence of settled differences in velocities for different layers, as soon as the particles come in motion under the action of some causes (outflow of matter, convection currents, turbulence, a. o.). In the huge atmospheres of the supergiants the effective value of the gravity will probably not remain constant in different layers and even will possibly change in sign. More than in any other stars one may expect here differences in the effective level for different atoms. Thus, the study of radial velocities from individual lines in spectra of supergiants is promising for the knowledge of certain details of structure of their atmospheres and processes taking place within them.

2. In the present paper are briefly exposed the results of measurement of the spectra of α Cygni, β Orion. and 67 Oph. The observational material was received at Simeiz (some tens of spectrograms, partly on fine-grained plates). For the first two stars we have found noticeable systematic differences in the velocities from different groups of lines. Obviously, one can speak chiefly of the differential effect, as there remains some uncertainty with respect to the zero point of velocity. We have used for control of the results received the published lists of wavelengths for α Cygni and β Orion. These sources will be quoted further as S. S. (1), O. S. (2), W (3) and S. D. (4), and the Simeiz observations as S. The source S. S. is of largest weight (very high dispersion and great number of lines). The source

Table 1

Hydrogen (α Cygni)

Source		Δ λ	p. e.	n
S	$H_8 - H_{19}$	+0.016 Å	±0.005	12
O. S.	$H_8 - H_{19}$	+0.024	.010	12
O. S.	$H_8 - H_{29}$	+0.014	.009	22
W	$H_8 - H_{19}$	+0.038	.019	12
W	$H_8 - H_{18}$	+0.015	.015	11
W	$H_8 - H_{28}$ (excluding H_{19})	+0.038	.016	18
W	$H_8 - H_{28}$	+0.058	.019	19
S. D.	$H_9 - H_{21}$	+0.049	.022	14

S. D. has the lowest weight (great accidental error and a considerable systematic one, rather uncertainly controlled). We give the values of $\Delta\lambda$ (observations—laboratory) for different groups of lines. Seriously blended lines were rejected. These values of $\Delta\lambda$ are very small, and thus the observations were considered in different combinations (Table 1).

Although the received values of $\Delta\lambda$ are small, the satisfactory agreement of four independent series of observations speaks in favour of the reality of a shift of about $+0.025$ Å in the mean. The cause of this shift may lie in a systematic error in the observations, or in the wrong value of the adopted radial velocity.

Table 2

Source		$\Delta\lambda$	p. e.	n	Elements
	Lines of Neutral Atoms and Resonance Lines (α Cygni)				
S	Resonance lines	—0.043 Å	±0.037*	6	Mn I, Cr I, Sr II, Ca II
S	» »	—0.099	.025	5	Mn I, Sr II, Ca II
S	Resonance lines plus Fe I (E. P. < 1.60)	—0.043	.016	13	Mn I, Cr I, Sr II, Ca II, Fe I
S. S.	Resonance lines	—0.054	.016	13	Mn I, Cr I, Al I, Ca I, Ba II, Sr II, Ca II
S. S.	Resonance lines plus Fe I (E. P. < 0.11)	—0.056	.013	20	Mn I, Cr I, Al I, Ca I, Ba II, Sr II, Ca II, Fe I (E. P. < 0.11)
W	Resonance lines	—0.030	.037	7	Mn I, Cr I, Sr II, Ca II
W	Resonance lines plus Fe I (E. P. < 0.11)	—0.045	.026	10	Mn I, Cr I, Sr II, Ca II, Fe I (E. P. < 0.11)
S	Neutral lines	—0.022	.018	10	Cr I, Mn I, Fe I, Mg I
S	Neutral lines without resonance lines	—0.045	.011	8	Fe I, Mg I
S. S.	Neutral lines	—0.033	.008	80	Fe I, Mg I, O I plus resonance atomic lines
S. S.	Neutral lines without resonance lines and Fe I (E. P. < 0.11)	—0.028	.008	65	Fe I, Mg I, O I
W	Neutral lines (region 2950—4674)	—0.049	.015	20	Fe I, Mg I, Mn I, Cr I
W	Neutral lines (region 3913—4674)	—0.058	.016	17	Fe I, Mg I, Mn I, Cr I
W	Neutral lines without resonance lines	—0.052	.015	17	Fe I, Mg I
W	Neutral lines without resonance lines and Fe I (E. P. < 0.11)	—0.046	.017	14	Fe I, Mg I
S. D.	Neutral lines	—0.032	.041	11	Fe I, Mg I
	Lines of Ionized Atoms (α Cygni)				
S	Ionized lines	—1.012 Å	+0.004	54	Fe II, Ti II, V II, Si II, S II
		—0.009	.003	53	Mg II, C II, Ni II, Ca II
S. S.	Ionized lines	+0.005	.003	305	Fe II, V II, Cr II, Ti II, Si II, S II, Cl II, Ni II, Mn II, Sc II, Al II, Mg II, C II
W	Ionized lines (region 3613—4674)	—0.004	.004	109	Do
S. D.	Ionized lines (with allowance for the systematic error of observation)	—0.010	.030	22	Fe II, V II, Ti II, Cr II, Si II, Ni II, Sc II

* The very high probable error is due to a large positive shift for Cr I 4254 (+18 km/s). This is confirmed by W. Apparently, this is due to the unknown line at 4254, measured separately by S. S.

But if we adjust the latter in such a way as to bring the systematic shift to zero, the systematic difference for the lines of neutral and ionized elements will increase, as we shall see it later.

The observed positive shift for H cannot be ascribed to the influence of possible emission components of hydrogen. Really, in the spectrum of P Cygni the hydrogen emission is strong and can be followed even until H_{23}, while its distorting influence on the profile and shift of the absoption lines can be felt not farther than H_9 ([5]). Besides, the systematic shift here is always negative. In the spectrum of α Cygni an emission component of variable intensity was found only for Hα, and it must obviously strongly affect the position of the absorption line Hα (Simeiz, 1.3 Å; Lick, 1.4; Yerkes, 0.6). But already for Hβ no traces of emission are to be seen, although a small shift of about—0.04 Å can be suspected. We shall return once more to the question of the reality of these positive shifts, when discussing the analogous results for β Orionis (Table 2).

Assigning to the sources S. S., S, O. S., W and S. D. the weights 2, 1, 1, 1 and 0.5, respectively, we get in the mean (Table 3).

Table 3

Hydrogen	+0.026 Å	+2.0 km/sec.
Resonance lines plus Fe I (E. P. < 0.11)	—0.050	—3.7
Neutral lines	—0.032	—2.4
Ionized lines	0.000	0.0

The probable error is 2.5 times less than the shift, and this speaks in favour of the reality of the latter. The shifts being of different sign, the zero point error will increase the effect for some line groups and reduce it for others, but will never remove it entirely. Some years ago Adams found chiefly from measurement of Fe lines the difference between neutral and ionized lines to be about—2.0 km ([6]).

3. β Orion. The spectrum of this star is less rich in ionized lines, and, with the exception of H and K, possesses no resonance lines at all. Here we have also less material for comparison of different wave-length lists. A noticeable shift for the lines of Ca II and Si II was first discovered by Adams and MacCormack ([6]), —6.8 and —4.3, respectively. This results was confirmed by the author. The latter found that the Mg II line also shows a shift of -3.5 ± 0.8. He came, besides, to the strange result that the velocity of β Orion. is 4 km in excess of the velocity of the component BC ([7]). The latter was suspected to be a spectroscopic binary ([8]). Using a dispersion of 2.9 Å, Sanford found in 1942 that a negative shift with respect to H is shown also by lines of Fe II, C II and He (the shift from the latter lines is small) ([9]). According to Sanford, the velocity of A from hydrogen lines is by 3.8 km in excess of the velocity of BC, but when determined from helium and ionized lines, is nearly equal to that of BC. More recent Simeiz measurements (including also the region 4494—4603) generally confirm and complete our old result. When rejecting the doubtful identifications and seldom measured lines, we find the following results (Table 4).

In the third column are given the results of Sanford.

We have considered also three other series of observations. Struve gives for ten stars mean values of wave-lengths for a great number of lines ([10]). This list contains a small number of wave-lengths based exclusively on β Orion. If the velocity from any line differs from that adopted for this star, the wave-length of this line will deviate from the laboratory value. Taking only the ions for which the number of measured lines is not less than two, we find following values (Table 5). The systematic shift for Fe II appears real. The value for S II could not be tested at Simeiz as these lines are blends at our dispersion. Sanford does not mention this ion at all.

We have also newly reduced the old series of observations of β Orion. by Frost and Adams ([11]), using the modern system of wave-lengths ([12]).

Table 4

H	+21.3 km	+22.9	
He	+20 9	+20.0	
Ca II	15.9	—	
Si II	17.6	17.0	
Mg II	17.8		
Fe II	18.7		
C II	20.4		
O II	18.5 ?	—	

Table 5

	Δ λ	p. e.	n
Fe II	—0.079 Å	±0.035	9
Fe II excluding 4389	—0.049	.011	8
Ca II	—0.030	.025	2
S II	—0.275	.081	2

Rejecting evident blends, moreover observed only once, we get (Table 6).

Table 6

Hγ	+21.2	1	17
He	20.9	4	45
Mg II	20.2	1	19
Fe II	19.3	2	6
Si III	16.1	2	3

The last two columns give the number of lines and the numbers of measurements. For the helium lines 4471 and 4713 we have adopted as standard the mean effective value of λ (mean value from numerous observations of B stars at Yerkes and Simeiz), and not the wave-length o the brighter component, as recommended by the I. A. U. ([12]). Such a replacement can be justified theoretically ([13]). Considering the high accuracy of these observations, one can speak of the reality of the shift for Fe II. Possibly, it holds also for Si III. A small shift can be seen also for Mg II. For the source S. D. we have (Table 7).

Table 7

H	— 0.043 Å	±0.040	6
He	— 0.015	.087	4
Si II, C II	— 0.137	.093	4
Si II, C II, Ti II, O II, Al II	— 0.080	.050	9

These results are, as mentioned above, of small weight. But here also, in agreement with other data, there appears to be seen a negative shift with respect to hydrogen for S II, C II and perhaps for other ions.

The reality of the differential effect for β Orion. is beyond doubt. But the question of the zero-point presents here also some difficulties. The velocity +23.6, as given by Moore, seems to be too high. It is true, the components A and BC are apparently connected physically, and recently the velocity of BC was determined [Mt. Wilson +19.1 as the element γ of a spectroscopic binary ([9]) and Simeiz +16.9±1.9 as velocity from unresolved lines]. But in this case also the zero-point for A may be considered as known with an accuracy not higher than ±1.5 km.

Two independent determinations (Mt. Wilson and Simeiz) show an excess for A (from H lines) over BC of the order of +4 km, and within the spectrum of the component A an excess of the same order for hydrogen with respect to ions (at least Ca II, Si II, Mg II, C II, Fe II). Possibly, to these ions must be added also Si III and S II. The lines of the latter two ions as well as of other ones, more seldom observed, are very faint, and no conclusions can be made with regard to them. For helium we have received at Simeiz only a very small negative excess, but according to more accurate measurements by Sanford, helium occupies an intermediate position between hydrogen and the ions. Considering the above mentioned accuracy for the zero-point, we can conclude that the systematic shift

for hydrogen is probably contained between +2 and +5 km, and for the ions between —1.5 and +1.5 km.

4. 67 O p h. In the spectrum of the third of supergiants studied the characteristic *c* is not well pronounced. Strictly speaking, from the lines of Fe II only 4233 is measurable. With regard to ions, more or less certain results are received for Ca II, Si II and Mg II (relatively to hydrogen —5.0±1.1 km, —1.9±1.0 and —2.8±0.8, respectively). Allowing approximately for the influence of interstellar calcium (accuracy about ±3 km), we get for Ca II a shift about zero. For helium we find +1.6±0.6. The question of the reality of the shift of the lines in 67 Oph. remains open, and at any rate this effect here is less than for α Cygni and β Orion.

5. We can compare the results for α Cygni and β Orion. for the hydrogen and ionized lines only, for resonance lines with the exception of H and K are not seen in β Orion. Keeping in mind the accuracy of the zero-point of velocity, we must nevertheless emphasize that in both cases we find for hydrogen a positive excess (of the order of +3.5 for β Orion. and +2 km for α Cygni). One may also admit that in the first approximation the ions in both cases show no systematic shift and characterize the velocity of the star. The accuracy of the latter result is probably of the order of β 1.5 km for α Cygni and β 2 km for β Orion. Although the values of the shifts found here are very small, the satisfactory agreement of independent series of observations and a certain similarity of the results for both stars speaks for their reality.

Generally for the reduction of measurements of the A stars the wave-length system of Rowland is used, and only for the hydrogen lines the laboratory values are taken. This results in unhomogeneity, as the solar lines show a systematic shift of +0.6 km due probably to the Einstein effect. Consequently, all lines other than hydrogen will show with respect to the hydrogen lines a shift of about—0.6 km. But this effect can account for only a small part of the phenomenon observed in supergiants, the more so as it does not apply to the source S. S. based on the laboratory system.

It has recently been found that the K term for the supergiants B_2—A_3 has a high negative value of about—5 km ([14]). If the above-mentioned positive excess for hydrogen is common for all white supergiants, the interpretation of the K term becomes still more involved. Hydrogen enters in the determinations of radial velocities of the supergiants with rather a high weight. As we have seen above, hydrogen does not probably characterize the velocity of the star, and the positive excess is a specific peculiarity of hydrogen itself. Allowance for this peculiarity will probably increase the negative K term by—1,—1.5 km. In connexion with the above results one must emphasize the very complicated character of the K term in supergiants, as it consists from some components of different origin.

α Cygni and β Orion. have only two resonance lines in common, H and K. The interpretation of the systematic displacements is complicated here by the influence of interstellar calcium. For β Orion. the total absorption of the interstellar calcium is probably no more than 0.20 Å, and of the blend about 0.70. For the distance of β Orion. the relative displacement of the interstellar calcium is probably of the order of—5 km. In this case the observed negative shift for H and K (about —6 km), when freed from the influence of interstellar calcium, must be higher still. If the motion of interstellar calcium is abnormally high in this region (say, —15 km), the observed shift of H and K in β Orion. may be ascribed to the influence of interstellar calcium. But this seems hardly probable. In the spectrum of β Orion. the lines of Na I, which are wholly or chiefly interstellar, show a shift of—7 km, and probably this is also the velocity of the interstellar calcium ions. Therefore the influence of the interstellar calcium upon the position of the observed blend cannot be considerable. As the effect of interstellar calcium is probably small, we cannot even decide whether it strengthens or reduces the observed displacement of H and K. The negative shift for the majority of ions (Fe II, Mg II, Si II, C II) with respect to hydrogen being—4 km, the residual effect for calcium ions may be estimated as about —2 km. As seen above, there are serious reasons to think that it is just these ions rather than hydrogen, that characterize

the stellar velocity, and in this case we should find for H and K in the spectrum of β Orion. the same effect as for those and other resonance lines in the spectrum of α Cygni. As the influence of interstellar calcium cannot be allowed for with greater accuracy than ±2 km, this question must be postponed till spectrograms of β Orion. with dispersion high enough to resolve the stellar and interstellar calcium lines will be available.

So far as the H and K lines in α Cygni are concerned, the question seems to be clearer for these lines. A shift of —2.7 km was found at Mt. Wilson,[6] and —2.5 at Simeiz [14] relatively to H and He. On a spectrogram of α Cygni recently obtained at the McDonald observatory [1] at very high dispersion it was found that H and K consist of two components, a stellar and probably an interstellar component. If this interpretation is correct, the shift for the first component is —0.09 Å. and for the second, about +0.18 Å. As was to be expected, the intensity of interstellar calcium is great, but the displacement of the lines is much higher than anticipated, and this illustrates how difficult it is to take into account the influence of interstellar calcium in the case of an observed blend. We have here an indication that the resonance lines of stellar calcium show a considerable negative shift. In the light of these and other data the question as to the difference or likeness of the behaviour of the calcium ions in the atmospheres of α Cygni and β Orion. remains open.

The reality of the positive and negative displacements found for different line groups appears probable, and this observed fact is important. In this connexion it is also worth while to point out the fact that the considerable negative shift for the resonance lines, and lines with very low excitation potential, in general, in the spectra of white supergiants, bears a certain analogy to what was recently found in the spectra of supergiants M, notwithstanding that both stellar classes are situated almost at opposite ends of the spectral classification. However, in the spectra of red supergiants this displacement is larger or even much larger. Recent spectrograms of α Orionis and other red supergiants by Adams [15] show often not even an asymmetric profile, but a doubling of resonance lines with a stronger violet component. This allows to suspect a corresponding doubling of lines in the spectra of white supergiants. Probably, this phenomenon can be interpreted not only in the sense that in the atmospheres of white supergiants an ascending motion of atoms and ions takes place in some layers, but also that there exists a descending motion of the same atoms and ions, or other elements in other layers. The existence of the ascending and descending motion of matter in the atmospheres of supergiants is a question of high importance. In atmospheres of usual stars this phenomenon is not observed, and, to judge from the Sun, it can attain here only an insignificant strength. Further discussion of this phenomenon will undoubtedly throw light upon one of the important sides of the problem of extended atmospheres.

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TECHNICAL PHYSICS

SPECTRAL DETERMINATION OF SULPHUR IN AQUEOUS SALT SOLUTIONS

By O. V. BLANK and N. S. SVENTITSKY

(Communicated by A. N. Terenin, Member of the Academy, 7. II. 1944)

Spectra of metalloids, of sulphur, for instance, are excited in an a. c. arc discharge between metal electrodes when the arc is shunted with a large capacity (1). The visible spectrum of sulphur that arises under these conditions has been investigated by the authors, and the results are set forth in the present paper along with some data which point to the possibility of spectro-analytical quantitative determinations.

When sulphate solutions are introduced into the flame of the arc, the spectrum of S II is excited. For the upper electrode of the arc a pointed copper bar was used, and the lower electrode was a copper disc, 1 mm thick and 20 mm in diameter, rotating in the vertical plane at a rate of 1 revolution per minute. The lower part of the disc was submerged in the solution tested. The discharge took place in the air between the electrodes across a thin layer of the solution which was delivered continuously by the disc in unvarying quantities. The shunting capacity was 60 μ F; arc current, 5 A; distance between electrodes, 1 mm. The slit of the spectrograph was illuminated by radiation from that portion of the flame close to the

Table 1

Wavelength in Å	Transitions according to Gilles data (3)	Intensities according to Ingram (2)	Wavelength in Å	Transitions according to Gilles data (3)	Intensities according to Ingram (2)
6287	$3d\ {}^2F_{7/2} - 4p\ {}^2P_{5/2}$	4	4716	$4s\ {}^4P_{3/2} - 4p\ {}^4S_{3/2}$	7
5660	$3d\ {}^4F_{5/2} - 4p\ {}^4D_{3/2}$	4	4552	$4s'\ {}^2D_{3/2} - 4p'\ {}^2P_{1/2}$	5
5640	$4s\ {}^2P_{3/2} - 4p\ {}^2D_{5/2}$	8	4464	$4p\ {}^4D_{7/2} - 5s\ {}^4P_{5/2}$	6
5606	$3d\ {}^4F_{9/2} - 4p\ {}^4D_{7/2}$	6	4456	$4p\ {}^4D_{1/2} - 5s\ {}^4P_{1/2}$	4
5565	$4s\ {}^4P_{5/2} - 4p\ {}^4D_{5/2}$	4	4432	$4p\ {}^4D_{3/2} - 5s\ {}^4P_{3/2}$	3
5509	$4s\ {}^4P_{3/2} - 4p\ {}^4D_{3/2}$	5	4392	$4p\ {}^4D_{5/2} - 5s\ {}^4P_{5/2}$	3
5473	$4s\ {}^2P_{1/2} - 4p\ {}^4D_{1/2}$	5	4294	$4p\ {}^4P_{5/2} - 4d\ {}^4D_{7/2}$	6
5454	$4s\ {}^4P_{5/2} - 4p\ {}^4D_{7/2}$	10	4267	$4p\ {}^4P_{3/2} - 4d\ {}^4D_{5/2}$	6
5428	$4s\ {}^4P_{1/2} - 4p\ {}^4D_{3/2}$	5	4189	$4p\ {}^4D_{3/2} - 4d\ {}^4F_{5/2}$	4
5345	$4s'\ {}^2D_{3/2} - 4p'\ {}^2F_{5/2}$	5	4174	—	5
5320	$4s'\ {}^2D_{5/2} - 4p'\ {}^2F_{7/2}$	7	4162	$4p\ {}^4D_{7/2} - 4d\ {}^4F_{9/2}$	10
5032	$4s\ {}^4P_{5/2} - 4p\ {}^4P_{5/2}$	5	4145	$4p\ {}^4D_{3/2} - 4d\ {}^4F_{5/2}$	8
5014	$4s\ {}^2P_{3/2} - 4p\ {}^2P_{3/2}$	3	4142	$4p\ {}^4D_{1/2} - 4d\ {}^4F_{3/2}$	8
4992	$4s\ {}^4P_{3/2} - 4p\ {}^4P_{3/2}$	3			

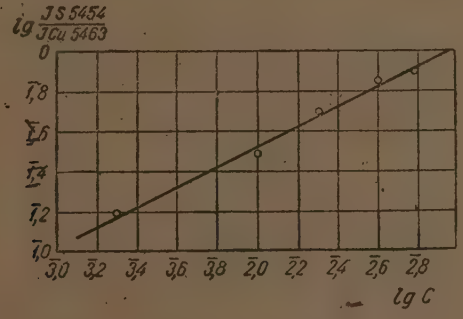
disc electrode. This portion was separated by a slit diaphragm placed in the plane of the magnified image of the arc. Aside from copper lines, S II lines, listed in Table 1, were observed in the spectrum under these conditions.

S II 5454 and S II 4162 are the most sensitive lines. They appear when the concentration of sulphur in the solution is of the order of some thousandth fractions of a per cent. A low content of sulphur can be estimated from the appearance of different lines, as indicated in Table 2.

Table 2

Concentration of sulphur in %	Spectrum indices
About 0.002	Only line 5454 is visible
» 0.01	Lines 5454, 5660, 5640, 5606 and 5509 are faintly visible; 5473 and 5565 have not appeared yet
» 0.02	5473 and 5565 make their appearance
» 0.08	S 5454 greater than, or equal to, Cu 5463 in intensity
Above 0.1	S 5454>Cu 5463

For more accurate determinations of sulphur the authors used the method of objective photometry and compared the intensity of the S 5454 line with that of Cu 5463. The figure is a calibrated graph for the estimation of sulphur in $CuSO_4$ solutions. Each point of the graph is an average of data from three photographic plates. In evaluating the relative intensities from the photometry data the background of the spectrum near the lines of sulphur and copper was taken into account.



Calibrated graph for the estimation of sulphur in $CuSO_4$ solutions

The intensity of the background was computed from the intensities of the measured spectral lines. If no allowance for the background is made, the angle of slope of the curve will be found to be less.

The reproducibility of quantitative determinations is characterized by a probable error of 10 per cent for a single measurement.

By this method sulphur can be estimated in solutions of other salts as well. It was found that addition of chromine salts greatly lowers the sensitivity of the sulphur tests.

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BIOPHYSICS

ENERGY MINIMUM FOR CHROMATIC VISION

By N. I. PINEGIN

(Communicated by S. I. Wawilow, Member of the Academy, 10. I. 1944)

This paper deals with the quantity of energy necessary for chromatic vision. The results set forth refer to the mercury line 546 mμ, lying near the maximum of photopic sensitivity. The observers and the method of measurement were the same as in the experiments on the determination of the quantity of energy required for visual effect. The only difference is that this time the threshold of the appearance of the colour was determined. The stray light in the monochromator was eliminated by a filter which let through only the 546 mμ line. The measurements were made without point fixation and refer to *fovea centralis*. Chromatic aberration was removed by means of negative spectacle lenses.

The results of the tests are tabulated below. In the table and elsewhere E denotes the threshold illumination of the cornea; F, the light flux falling on the retina; J, the illumination of the retina. The absorption of radiation from 546 mμ in ocular media and in the cones themselves remains unknown and has not therefore been taken into account.

The light flux falling on the retina was computed from the formula

$$F = \frac{E}{h\nu}(1-r)\sigma$$

where $h\nu = 3.6 \times 10^{-12}$ erg is the energy quantum of the monochromatic radiation 546 mμ; $r = 0.05$ is the reflection losses of the cornea; $\sigma = 0.33$ cm² is the area of the pupil of the eye (the average diameter of the eye, 6.5 mm).

Lower Limit of Energy for Stimulation of Colour Vision

Observer	Age	E, $\frac{\text{erg}}{\text{sec.cm}^2}$	F, $\frac{\text{quanta}}{\text{sec.}}$	J, $\frac{\text{quanta}}{\text{sec. mm}^2}$	J_c
P.I.	37	1.71×10^{-6}	1.42×10^{5}	1.61×10^{7}	113.4
C.I.	17	2.66×10^{-7}	2.21×10^{4}	2.51×10^{6}	17.0
M.A.	21	2.50×10^{-6}	2.08×10^{5}	2.36×10^{7}	160.2
E.N.	29	2.75×10^{-6}	2.29×10^{5}	2.60×10^{7}	176.5
D.I.	19	4.25×10^{-6}	3.54×10^{5}	3.01×10^{7}	204.4
P.G.	22	1.24×10^{-7}	1.03×10^{4}	1.17×10^{6}	7.9
B.N.	25	1.57×10^{-7}	1.31×10^{4}	1.49×10^{6}	10.1
K.D.	15	7.12×10^{-7}	5.93×10^{4}	6.74×10^{6}	45.8
Mean		1.56×10^{-6}	1.3×10^{5}	1.48×10^{7}	100.5

The illumination of the retina was evaluated by the formula $J = F/a$, where $a = 0.0088$ mm² is the area of the image on the retina. After establishing the illu-

mination of the retina, we can calculate the number of quanta per second falling on a cone. For this purpose we may use Oesterberg's [1] data, according to whom there are 147300 cones per 1 mm² in the centre of *fovea centralis*.

In the last column of the table the number of quanta J_c falling upon a cone is given. This number varies from 8 to 200, according to the observer, making an average of 100 quanta per second.

So it is necessary for the stimulation of chromatic vision that a cone have 100 quanta per second falling on it, as an average, provided the neighbouring cones are stimulated.

Let us now compare our data with the reports of other authors. Monroe [2] obtained for F (552 mμ) a value of 3.63×10^4 quanta/sec. as an average for 20 observers. The area of the image on the retina in his experiments was 0.2826 mm². Accordingly, the illumination of the retina J was 1.3×10^5 quanta/sec. mm². In the experiments described in this paper the angle subtended by the stimulus at the eye was 21′, while in Monroe's experiments it measured 2°2′.2.

If the result obtained by him be referred to a visual size of 21′, one will obtain, under Ricco's law, a 6.3 times higher estimate of J, that is 8.2×10^5 quanta/sec. mm². This will mean that 6 quanta fall on a cone in a second. Goodeve [3] evaluated the illumination of the retina for 556 mμ as 2.83×10^5 quanta/sec. mm² (with $a = 0.0735$ mm²). In his experiments the image on the retina was not a round shape. If it were round, the angular size of the stimulus would be 1°2′. The illumination of the retina, if referred to the stimulus size of 21′, would be 3 times higher, that is 8.5×10^5 quanta/sec. mm². We again have 6 quanta per second falling on a cone.

A comparison of our results with those obtained by Monroe and Goodeve shows that our data are 17 times higher than theirs. To account for so strong a divergence, one may suppose that scotopic vision was not eliminated from their experiments.

The absolute threshold of scotopic sensitivity for 546 mμ, as measured under similar conditions with the same observers [4], is 5.62×10^{-3} erg/sec. cm²; the illumination of the retina for a pupil area of 0.5 cm² is 8×10^{-4} quanta/sec. mm². If in this case the vision were photopic instead of scotopic, one quantum per second would fall on a cone.

As Monroe and Goodeve found 6 quanta to fall on a cone in a second, there is, indeed, some reason in our surmise that scotopic vision was allowed in a certain measure to take part in their experiments along with photopic vision.

If so, it may be stated that in the case of monochromatic radiation 546 mμ about 100 quanta per second should be sent to a cone for the stimulation of colour vision.

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PHYSICAL CHEMISTRY

ON TYPES OF KINETIC CURVES IN CHAIN REACTIONS

II. CONSIDERATION OF THE INTERACTION OF ACTIVE PARTICLES

By N. N. SEMENOV, Member of the Academy

Sometimes one comes across the opinion that the chain theory supposedly leads to the conclusion that kinetic curves of the autocatalytic type, which we examined in communication (1), are obtained for all reactions with branched chains.

In reality only the condition of limits and the law of the initial acceleration of these reactions are of a universal nature. This I strove to prove both theoretically and by an analysis of numerous experiments in my book «Chain Reactions». A more rigid and general proof of this is given in one of my recent papers (2). As for the kinetic curves describing the entire course of the transformation, the simplest type of chain reaction that I examined briefly in my book and communication (1) leading to symmetrical curves of the kinetics or to a law of the autocatalytic type, is a particular case of the kinetics of chain reactions, although one not infrequently met with in experiment.

As the transformation develops, there accumulate in the system intermediate and end products which, as frequently happens, in their turn begin to react with the active centres of the chain reaction and distort the course of the chemical transformation.

Due to these causes, we get kinetic curves of most diverse types in experiment. The most general of the perturbing causes pointed out above is the interaction between molecules of the active intermediate product (between active centres) of the chain reaction. I briefly analysed it in Chapter 3, Paragraph 8 of my book. Let us now look into it in greater detail.

The active intermediate product easily reacts with molecules of the initial substance, and it is this that gives rise to the development of a chain. But all the more easily should the molecules of this active substance react with themselves

$$(H + H + M = H_2 + M \text{ or } SO + SO + O_2 = 2SO_2 \text{ and the like})$$

Thus, only at the start of the reaction, when the concentration of the active substance is small, may we disregard this process of interaction. When considering the complete course of the transformation, however, we must take into account this effect as the fundamental property of any chain reaction. Only in particular cases may this interaction turn out to be small, and only in these particular cases will a simple autocatalytic law of the course of the reaction be justifiable. In the general case, however, we will have a more or less marked deviation from this regularity. We must take into account destruction of the active substance at a rate Bn^2, where n is the number of active centres per unit of volume. And so, the number Bn^2 has to be added to the right-hand side of the first of the ordinary chain reaction equations in the form we adopted in communication (1). This modifies

the expression as follows:

$$\frac{dn}{dt} = n_0 + an - Bn^2; \quad -\frac{dU}{dt} = n_0 + en \tag{1}$$

Or, introducing the same notation that we used before [in communication (1)]

$$\eta = \frac{U - U_0}{U_0}; \quad \xi = \frac{n}{U_0}; \quad a = f(1-\eta); \quad e = c(1-\eta);$$

$$n_0 = n_0'(1-\eta); \quad \nu_0 = \frac{n_0'}{fU_0}; \quad \tau = ft$$

and introducing $b = BU_0$, we may rewrite (1) in such a form:

$$\frac{d\xi}{dt} = (\nu_0 + \xi)(1-\eta) - \frac{b}{f}\xi^2; \quad \frac{d\eta}{dt} = \left(\nu_0 + \frac{c}{f}\xi\right)(1-\eta) \tag{2}$$

As was shown in the earlier paper, at sufficiently small * ν_0 for ξ and $\eta \gg \nu_0$, we may make use of the simplified equations (2) in the form:

$$\frac{d\xi}{dt} = \xi(1-\eta) - \frac{b}{f}\xi^2; \quad \frac{d\eta}{d\tau} = \frac{c}{f}\xi(1-\eta) \tag{3}$$

Dividing the first of these by the second, we eliminate τ and get

$$\frac{d\xi}{d\eta} = \frac{f}{c} - \frac{b}{c}\frac{\xi}{1-\eta} = f' - b'\frac{\xi}{1-\eta} \tag{4}$$

where $f' = \frac{f}{c} = \frac{1}{q}$ and $b' = \frac{b}{c}$. Integrating equation (4) under the condition $\xi \cong 0$ when $\eta \cong 0$, we get

$$\xi = \frac{f'}{b'-1}[1-(1-\eta)^{b'-1}](1-\eta) \tag{5}$$

and then, substituting (5) into (3),

$$\frac{d\eta}{d\tau} = \frac{1}{b'-1}[1-(1-\eta)^{b'-1}](1-\eta)^2 \text{ **} \tag{6}$$

For $b' = 0$, *i. e.* when there is no interaction, equation (6) obviously reduces, as an approximation, to the autocatalytic equation $d\eta/d\tau = \eta(1-\eta)$ which thus is a particular case of the general equation (6).

For $b' = 2$, equation (6) becomes:

$$\frac{d\eta}{d\tau} = \eta(1-\eta)^2 \tag{7}$$

which gives a rate maximum when the transformation has run through one third of its course. Calculating $\frac{d\eta}{d\tau}$ for different values of b' as a function of η, we get the system of curves given in Fig. 1.

As b' increases, the rate maximum shifts closer and closer to the start of the transformation. The value η_{max} corresponding to the reaction rate maximum, is determined by the relations:

$$(1-\eta_{max}) = \left(\frac{2}{1-b'}\right)^{1/(b'-1)} \tag{8}$$

and

$$\left(\frac{d\eta}{d\tau}\right)_{max} = \frac{(1-\eta_{max})^2}{1-b'} \tag{9}$$

Let us compare the quantities b and c, assuming the reactions Cn and Bn^2 bimolecular: $c \cong \sqrt{2}\pi\sigma^2 u U_0 e^{-E/RT}$; $b = BU_0 = \sqrt{2}\pi\sigma^2 u U_0 e^{-\varepsilon/RT}$. Whence it follows that $b' = \frac{b}{c} \cong e^{\frac{E-\varepsilon}{RT}}$.

---

* We confine ourselves here to a consideration only of such reactions where ν_0 is small, or, in other words, a clearly defined induction period is found.

** At the start of the reaction, when η is small and when consequently it may be assumed that $(1-\eta)^{b'-1} \cong 1-(b'-1)\eta$ and $1-\eta \cong 1$, we get the usual law describing the initial acceleration $d\eta/d\tau = \eta$. This is due to the fact that in the initial phase ξ is small and $b\xi^2 \ll f\xi$.

In many (if not in the majority) of the cases the energy of activation E of the reaction of the active substance with the initial one should be greater than the energy of activation of the reaction of the molecules of the active substance with one another. In this case $b' > 1$. In the case where the molecules of the active intermediate product are atoms or radicals which recombine with one another without an energy of activation but as a result of triple collisions, $b' = e^{E/RT} \cdot 10^{-3} p$, where p is the pressure of the initial substance in atmospheres.

At very low pressures, b' may be small, and at high ones will attain big values.

We may replace the dimensionless time $\tau = ft$ in equation (6) by the dimensionless time $\tau' = \frac{f}{b'-1} t$, where t is the true time. Then equation (6) is rewritten in such a form:

$$\frac{d\eta}{d\tau'} = [1-(1-\eta)^{b'-1}](1-\eta)^2 \qquad (10)$$

In this case upon varying b' from 1 to infinity, the system of curves in Fig. 1 assumes the shape of the system of curves in Fig. 2. The asymptotic curve $b' = \infty$; $d\eta/d\tau' = (1-\eta)^2$ corresponds to a simple bimolecular relation*.

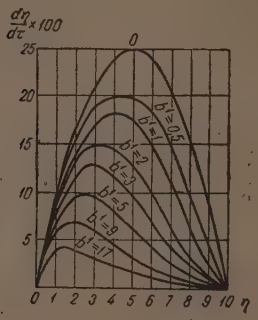

Fig. 1

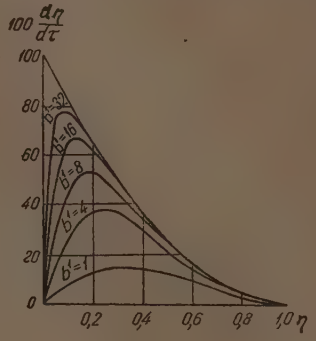

Fig. 2

Proceeding from the system of curves obtained, we may without difficulty construct the dependence η as a function of τ (kinetic curves).

To do this we note that at the start of the transformation, while $(b'-1)\eta \ll 1$, we may (as pointed out above) discard the interaction, and in order to find η as a function of τ for $\eta \ll \frac{1}{b'-1}$, integrate the system of elementary chain reaction equations

$$\frac{d\xi}{d\tau} = \nu_0 + \xi \quad \text{and} \quad \frac{d\eta}{d\tau} = \nu_0 + \frac{c}{f}\,\xi = \nu_0 + q\xi \qquad (11)$$

As we saw in communication (1)

$$\xi = \xi_0 (e^{\tau} - 1) \quad \text{and} \quad \eta = q\nu_0 \left[e^{\tau} - 1 - \left(1 - \frac{1}{q}\right)\tau \right] \qquad (12)$$

From equation (11) we find that value of τ_1 which corresponds to some value of $\eta \ll \frac{1}{b'-1}$ and $\eta_1 \gg \nu_0$ that we have chosen.

---

* The system of curves in Figs. 1 and 2 may be characterized as follows. The first gives a comparison of the true rates $d\eta/dt$ at constant f and different b'; the second, at constant $\frac{f}{b'-1}$ and different b'.

Starting with this value of η_1, we may find τ from equation (6), whence

$$\tau = (b'-1)\int_{\eta_1}^{\eta} \frac{d\eta}{[1-(1-\eta)^{b'-1}]\,(1-\eta)^2} + \tau_1 \qquad (13)$$

The integral may be evaluated by employing, for example, the elementary procedure we used before [in communication (1)]. In Figs. 3 and 4 are given as a case in point two calculated curves: 1) for $b'=2$ and 2) for $b'=33$. The induction period determined by relation (12) is calculated for the case $\nu_0 = 0.000033$ and $\frac{1}{q} = \frac{f}{e} = f' = 0.2$. The smaller the values of ν_0 chosen, the longer the induction period will be.

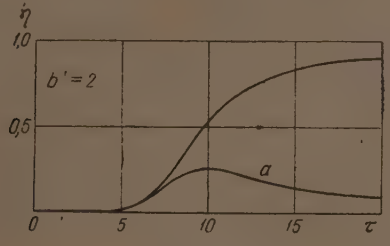

Fig. 3

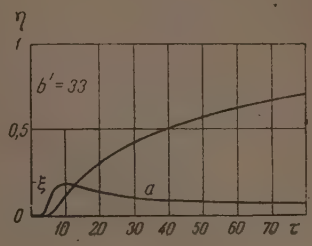

Fig. 4

In the same figures the a curves give the dependence of the concentration ξ of the active intermediate product, calculated with the help of formula (5), upon the reaction time. The scale for these curves has been magnified five times, and in Fig. 4, 32 times. ξ was calculated for $q = \frac{c}{f} = \frac{1}{f'} = 5$. The smaller q, the greater will be ξ.

Kinetic curves of the type pictured in Figs. 3 and 4 and of the intermediate type are frequently encountered in experiment.

In the derivation of all formulae we assumed that the quantities B and b do not depend upon $(1-\eta)$, in other words, we assumed that the initial substance does not figure in the interaction of the active centres. If the molecules of the initial substance do take part in the interaction (as, for example, in the reaction $SO+SO+O_2=2SO_2$), $b\xi^2$ has to be replaced by $b\xi^2\,(1-\eta)$. In this case instead of the system of equations (3) we will write:

$$\frac{d\xi}{d\tau} = \left(\xi - \frac{b}{f}\,\xi^2\right)(1-\eta) \quad \text{and} \quad \frac{d\eta}{d\tau} = \frac{c}{f}\,\xi\,(1-\eta)^* \qquad (14)$$

whence we get

$$\xi = \frac{f'}{b'}\,(1-e^{-b'\eta}) \qquad (15)$$

$$\frac{d\eta}{d\tau} = \frac{1}{b'}\,(1-e^{-b'\eta})\,(1-\eta) \qquad (16)$$

or

$$\frac{d\eta}{d\tau'} = (1-e^{b'\eta})\,(1-\eta) \qquad (17)$$

---

* Strictly speaking, this equation has to be written in the form:

$$\frac{d\eta}{d\tau} = \left(\xi - \frac{c}{f}\,\xi^2\right)(1-\eta) + b\,\xi^2(1-\eta) \qquad (14')$$

However, to simplify the solution, and taking into account that all these equations give similar kinetic curves, we confine ourselves to a consideration of system (14). A detailed study of a complete equation of the type of (14′) was made in 1942 by Emanuel in his thesis.

The corresponding system of curves given in Fig. 5 very closely resembles those in Fig. 2. Still differences do exist just the same, inasmuch as the asymptotic curve $b'=\infty$ in this case is a straight line corresponding to the monomolecular law $d\eta/d\tau'=(1-\eta)$.

In Fig. 6 there is given the curve η as a function of t for $b'=30$ for this case. We see that this curve differs somewhat from the corresponding curve in Fig. 3 of the previous cases, even though it resembles the latter*.

It should be noted besides that in all our examples considered in both communications we assumed that the quantities a and c are linear functions of $(1-\eta)$. However, in complex reactions involving several types of active centres these quantities themselves consist of the products of several quantities a_1, a_2, a_3, ... *etc.*, determining the reaction rates of the different types of active centres (2). That is why a and c in equation (1) may be a more complex function of $(1-\eta)$, *e. g.* may be proportional not to $(1-\eta)$ but to $(1-\eta)^2$.

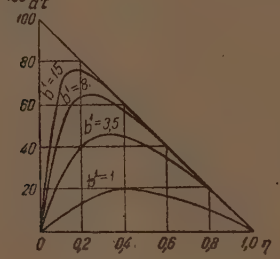

Fig. 5

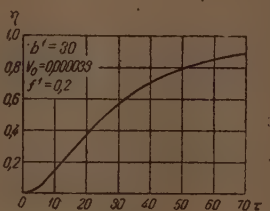

Fig. 6

Thus, besides the two types of interaction that were considered, a number of others are possible.

However, all these cases differ no more than the two we considered, which therefore sufficiently characterize the influence of the interaction of chains upon the kinetics of a chain reaction. In some cases chain branching arises upon interaction of active products. Here interaction leads to the opposite, shifting the maximum velocity in the direction of greater (more than 50) per cent transformation.

Many other interesting phenomena arising in this case were considered in my book and papers, as well as in papers by Neumann on the origination of cold flames, by Kokochashvili on the photochemistry of H_2+Cl_2, and the like. Therefore I will not go here into an analysis of these cases.

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* Curves of the type in Figs. 3, 4, 6, and diverse intermediate curves (for different b') are frequently encountered in experiment [for example, in the decomposition of ozone in the presence of bromine (3), the oxidation of hydrogen sulphide (4), the oxidation of methane and ethylene according to Bone, and many others].

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GEOCHEMISTRY

ON THE CHLORINE-BROMINE COEFFICIENT OF UNDERGROUND WATERS

By A. P. VINOGRADOV, Corresponding Member of the Academy

Attempts of reconstruction those geochemical processes which are responsible for the formation of definite beds, rocks, water basins, *etc.* are usually based on data concerning the quantitative distribution of chemical elements in the respective rocks, waters, *etc.* No less important in this respect is the analysis of the ratios of certain pairs of chemical elements, closely related as to their properties, *e. g.* K/Rb, Ni/Co, Ca/Sr, Cl/Br, *etc.* It stands to reason that the lesser the number of physical-chemical processes liable under different conditions in the Earth's crust to disturb the usual or, better to say, the normal ratios for a given pair of chemical elements, the more reliable are our geochemical extrapolations based on an analysis of these ratios. It is in this sense that the author believes the data for Cl/Br to be underestimated, in particular in connexion with the problem of the origin of underground (petroliferous waters, *etc.*) mineralized waters and brines.

Thousands of known underground water analyses indicate considerable variations of the numerical values of the Cl/Br ratio, not infrequently from 100 to 2000—5000.

Let us consider as normal a Cl/Br ratio equal to 300 on ground of what will be exposed below.

Normal sea water has a Cl/Br ratio=300*, be it a water from great oceanic depths, or freshened water of shallow seas (*e. g.* the Azov, Baltic and other seas). Bearing out of salts by rivers does not disturb this ratio of Cl/Br in the water of seas. In fact, if we assume, as V. Goldschmidt did, for some of the chemical elements that to the share of each kilogram of sea water falls 600 g of primary (magmatic) rock, which passed through the whole cycle of weathering, we shall have:

	Average content in magmatic rocks, g/kg	Amount brought in grams per 600 g of magmatic rock	Actual content in sea water g/kg	Content in sea water, % to amount brought-in
Cl	0.5	0.3	18.9	6300
Br	0.002	0.0012	0.065	5420

In other words, the Cl/Br ratio of sea water** is affected neither by the removal of Cl and Br by decomposition of rocks, nor by erosion of the continent. The

* From hundreds of determinations the Cl/Br ratio is more precisely equal to 293.

** It seems possible that in the waters of oceans there proceeds at a geological time scale a small enrichment with bromine, *i. e.* a decrease of the value of Cl/Br, as a result of a disproportionally great loss of chlorine by the ocean in the form of NaCl deposits on the continent.

mass of the chlorine and bromine in sea salts is of volcanic origin. On the other hand, in volcanic gases too a Cl/Br ratio approaching 300 should be expected, which on the whole does not contradict the direct, though few determinations of Cl and Br in gases and sublimates of present-day volcanoes.

What are then the processes taking place in the Earth's crust, which may disturb the Cl/Br ratio in waters? The following processes may be named: (a) the formation of variously soluble combinations of Cl and Br; (b) their different sorption by rocks; (c) their dilution by waters with NaCl; (d) the sea precipitation of salts (halogenesis). As to the formation of insoluble compounds of Br, of Br minerals, all of them are only of mineralogical interest. Not infrequently it is being assumed that the variable value of Cl/Br in waters is due to a selective sorption of Br (or Cl) by rocks. We cannot neglect the fact of a somewhat higher Br content and a corresponding shift of the Cl/Br ratio, *e. g.* in peats. The sorption* takes place from fresh waters, from diluted solutions with a Cl content of about 1×10^{-3} per cent, and Br, about 2×10^{-6} per cent. This process does not bring about a high concentration of Br, neither does it produce any marked geochemical effect and is not related to mineralized waters (to strong solutions). As to the latter, it is well known that between solutions and bottom sediments (muds) a chemical equilibrium is established. Not a single case is known where these muds (mud water, extracts, pressing out) would have a Cl/Br ratio appreciably above or below 300. After the settling of NaCl the Cl/Br ratio in the bottom deposits sharply increases, and it is in the process of further halogenesis, only since the moment of formation of a series of solid mixed crystals between $MgCl_2 \cdot 6H_2O$ and $Mg\,Br_2 \cdot 6H_2O$, on the one hand, and KCl and KBr, on the other, in sediments containing sylvinite and carnallite, that the Cl/Br ratio becomes less than 300.

At the same time, it is well known that owing to this process of concentration of sea water and settling of salts, $CaSO_4 \cdot 2H_2O$, NaCl, *etc.*, there is left the liquid phase, a bromine brine with a $Cl/Br < 300$. Thus, the sea halogenesis is in fact the most important geochemical process markedly disturbing the Cl/Br ratio in waters and brines. Finally, the direct solution by mineralized waters of salt halite-stocks or a dilution of these waters by water originating as a result of washing of salt domes and salt beds, is also an efficient process, leading to a disturbance of the Cl/Br ratio in waters, but now towards $Cl/Br > 300$.

In this way, the underground mineralized waters with a Cl/Br ratio approaching 300 (usually 300—400) will be termed here waters with a normal Cl/Br coefficient. This type of waters is the most widespread one. It is known over vast areas of oil fields of the Appalachian lowland, in the Midcontinent of the USA, resting upon sediments of different age. In the USSR, within the Russian plain, in the Palaeozoic strata there occur the same waters. They are known within the Siberian saliferous basin from the Yenissei to the Lena, within the petroliferous fields of Azerbaidjan, Grozny, Turkmenistan, *etc.* They are known in any country and their description is out of the scope of this paper. These waters should be considered as derivates of the waters of the normal ancient sea. The waters of the normal sea had been buried with the sediments. In the course of their subsequent history they underwent transformations under the influence of their interaction with rocks, as a result of which their salt composition became different from that of their original source. The Cl/Br ratio was not affected thereby, and remained near 300. The genesis of these waters was thus related to sea deposits developed over immense areas of the sea bottom, which absorbed the normal water of the sea, as the latter grew shallower. This sea which had simple non-dissected shores, upon a lowering of its level exposed huge coastal plains, hiding the waters of the regressing sea in their sediments.

The underground waters with a $Cl/Br < 300$, most frequently about 100—150, are exceedingly rare as compared to the waters of the former type. For the USSR the following might be listed: the group of the so-called deep waters of the Daghe-

*This process takes place as a possible result of a chemical binding of Br, *e. g.* by substances of the type of phenols, *etc.*

stan region (Berikly, Dag-ogni, *etc.*) with a Cl/Br about 200; the Lower Permian waters (Verkhnie Chussovskie Gorodki) with a Cl/Br about 150; the waters from the Carboniferous of Krasnokamsk (Severokamsk, Polazny) with a Cl/Br about 120.

Their composition* approaches that of the brine of salt lakes. Along the shores of South America, of the Mediterranean Sea in Africa, of the Black Sea in the Crimea, the coasts of India, *etc.*, in the coastal areas of the tropical and subtropical seas there are known numerous salt lakes which have completely or partly lost connexion with the sea and contain a brine, the Cl/Br of which generally varies within the range of 40—100 (e. *g.* in the Crimea, Lake Genichesk with a Cl/Br=78; Lake Saki, 40; Lake Sebkha el Melah, Tunis, 38, *etc.*)**.

The author considers the underground waters with a low value of the Cl/Br as derivatives of concentrated sea water, a residual brine of a superficial origin, subsequently buried. The process of their formation was also going on under conditions of a tropical and subtropical climate, in the belt of a dissected young shore line with bays to which the clastic material was supplied, shores with atolls, barrier reefs, among which lagoons and salt lakes originated, in which bromine brine was accumulating.

The «failed» sylvinite-carnallite sediments in the form of a brine of varying concentrations (and different Cl/Br) would subsequently become sedimentation waters (brine) and ultimately underground edge waters with a Cl/Br ratio$<$300.

Finally, waters with a Cl/Br$>$300 are certainly more widespread than those with a Cl/Br ratio $<$300, and are in this sense subordinate to waters with a normal Cl/Br coefficient. They are of a regional distribution as, for example. in the Archangelsk, Emba regions and elsewhere. Their origin is related, as it is already evident, with a dissolution of stocks and beds of NaCl. It is to the destruction of the NaCl stocks of the Ural-Emba province that the enrichment with salt of the Aral-Caspian region and the high value of Cl/Br of the Aral and Caspian seas (Cl/Br equal to 1300 and 663, respectively) are partly due. Naturally enough, the origin of underground waters with a Cl/Br ratio $>$ 300 is connected with the regions of the ancient sea, where a process of salt bed and salt dome formation went on, which must have resembled the picture of the sea with a lagoonal shore just outlined.

Thus, according to their Cl/Br coefficient, the underground waters may be subdivided into derivatives of (a) normal sea water with a Cl/Br ratio=300, (b) residual brine of sea salt lakes with a Cl/Br ratio$<$300, and (c) a dissolution of deposits of NaCl*** with a Cl/Br ratio$>$300. In nature all the transitions between these three main types are encountered. Waters with a Cl/Br ratio$<$300 and those with Cl/Br$>$300 may be further differentiated according to the grades of saturation, which is our immediate task.

A correlation of the values of the Cl/Br ratio with the regularities observed in the general ionic composition of underground waters permits of a closer approach to the conditions under which these waters are formed. We did not touch at this problem in the present note, our purpose being to focuss the reader's attention upon the origin of the various values of the chlorine-bromine coefficient in underground waters.

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* As a rule, without SO_4, brines rich in Mg and K.

** The water of the Dead Sea has a Cl/Br ratio=38, and in the author's opinion is of the same origin. The water of this sea presents a residue of the brine of numerous lakes which flowed into a graben.

*** This may be also a dissemination of NaCl in sedimentary rocks (enrichment with salt).

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BIOCHEMISTRY

ALTERATION OF CARBOHYDRATES IN GRAINS OF WHEAT GRAFTED ON RYE ENDOSPERM

By A. A. SHMUCK

(Communicated by A. A. Richter, Member of the Academy, 19. IV. 1944)

In a series of works issued from this Laboratory we were successful to demonstrate that profound changes take place in the composition of alkaloids of tobacco as a result of reciprocal grafts of the latter on other plants. These data go fully to refute the idea prevalent heretofore, *viz.* that transplanted plants are able of autonomous and independent development.

We have shown that *Nicotiana tabacum* grafted on *N. glauca* looses its ability to accumulate nicotine, but contains instead a different alkaloid, the anabasine(1). The grafting of *N. tabacum* on *Solanum lycopersicum*, *Datura stramonium* or *Atropa belladonna* causes a total absence of nicotine in the tobacco plant, whereas opposite grafts of *S. lycopersicum*, *A. belladonna* or *D. stramonium* on *N. tabacum*, even when deprived of leaves, result in a considerable accumulation of nicotine in the plants (2). We have also found that the alkaloid nornicotine, peculiar to *Nicotiana glutinosa*, vanishes as soon as this plant is grafted on an alien root(3).

All these investigations have fully been confirmed by a number of subsequent studies (4). It seemed highly interesting to find out whether these biochemical changes taking place in the grafted plants are typical of the tobacco alkaloids only, or other organic groups entering into the composition of plants are also liable to analogous profound changes, when grafted.

Prof. W. E. Pissarev kindly put at our disposal very interesting material which had been obtained by him jointly with N. Vinogradova by grafting wheat on rye endosperm. These authors succeeded in growing plants by transplanting embryos of wheat kernels on rye endosperm. The wheat was grown until full ripening and fruiting. The variety under experiment was *Lutescens* 62 grafted on the endosperm of summer wheat from East Siberia.

The writers point out certain morphological features that distinguish the grain of the wheat grafted from the control.

According to the data of usual agrochemical analysis, the composition of the grain of the wheat grafted differed but little from that of the controls; the only thing to be noted is that the former was somewhat higher in nitrogen and protein, but contained less starch. When, however, gluten was extracted from the flour prepared with grafted and control wheat, clear-cut and peculiar distinctive features could be revealed; these were not only quantitative, but also qualitative.

In the first line there was a sharply pronounced difference in the colour of the gluten obtained. The gluten prepared with grains of the control wheat showed the usual light-pink colour, while that made from grains of the «grafted» wheat assumed the colour of rye dough, being dark-brown.

Such a difference in the colour of gluten seems to be due to a different contents of tyrosin and a varying activity of tyrosinase. The difference becomes especially

salient when the dough prepared with flour and water is distributed in a thin layer over a glass and placed for some 12—15 hours in an exsiccator with water at 40°C. A dough prepared with grains of wheat grown on the endosperm of summer rye will then assume a dark-brown colour approaching that of rye bread.

According to investigations by Tillmans ([5]) and also by Kretovich ([6]), the peculiar distinction between the grain of rye and that of wheat consists in their different contents of the carbohydrate trifructosane, $C_8 H_{30} O_{15}$. This distinction is so peculiar that it enables one easily to detect an admixture of rye-flour to wheat-flour, even if it is as low as 10 per cent. For this purpose a special procedure has been worked out, of which we made use when investigating our grain. This procedure consists in the following: 5 g of flour are shaken during 15 minutes with 20 ml of 70° alcohol, after which the mixture is cooled under stirring for 10 minutes at a temperature of—3°C. Upon settling the extract is filtered; it should be noted that extracts from grains of «grafted» wheat show thereby a darker colour than extracts from control wheat. 10 ml of extracts filtered off are then added 0.5 ml of a normal solution of caustic soda in 70° alcohol; in the case of «grafted» wheat this brings about the separation of a considerable precipitate of trifructosane, while only quite a negligible turbidity appears in the solution with extracts from control wheat.

The weight of trifructosane isolated from 5 g of «grafted» wheat made up 0.14 g. After hydrolysis with 2 per cent hydrochloric acid, reaction for ketose invariably succeeds in a most distinct manner, and the hydrolysate shows the levorotatory habit peculiar to the ketose.

It is thus evident that the grain of a wheat «grafted» on rye endosperm contains considerable quantities of a carbohydrate which is typical of rye and is absent in the grain of wheat.

It is left no room to doubt that with regard to the carbohydrate complex the scion produces a strong influence upon the stock even in the case where the scion itself fails to develop. The nutrition of the growing scion in the earliest stages seems to determine the subsequent biochemical profound changes that take place in a mature plant.

An important part in this influence belongs probably to those hormones which are contained in the endosperm of the rye; passing into the wheat grafted, they affect the trend of the biochemical processes.

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HISTOLOGY

ON PECULIARITIES OF TEXTURE OF SKIN IN KARAKUL SHEEP

By N. V. POPOVA

(Communicated by L. A. Orbeli, Member of the Academy, 24. XII. 1943)

The skin fulfils the most various functions of the organism and cannot do otherwise than reflect by its microscopical texture the definite morphological regularities proper to the animal in accordance with a given character (breed, sex, age, constitution, *etc.*). In this juncture it is of particular interest thoroughly to investigate the skin of the karakul sheep, which when born already has a curled wooly skin of a peculiar and rather regular pattern. According to the type of the curl, the pattern can be subdivided into several classes, such as beetle, bean, crest, *etc.*

Herre and Rabes (3) subdivide the skin of karakul sheep into four layers: 1) the epidermis, 2) the subepidermal layer, 3) the intermediate layer, lodging the hair-roots and sweat glands, and 4) the reticular layer of the skin, passing into the subcutaneous fat tissue.

The data secured by the present author who studied the texture of the skin in adult karakul sheep go to support this scheme, as well as the microscopic structure of each separate layer, suggested by the writers cited above.

Peculiarities Connected with Constitution. According to their constitution, karakul sheep are usually classed by breeders into three types, the delicate, robust and coarse. Every type of constitution is matched by a corresponding property of the skin and, accordingly, by a corresponding quality of the curl, which may be small, large or medium, *etc.*

Thus, though the constitution of the sheep is taken into account in stock-breeding, the type of constitution is mostly determined merely from the external characters of the animal's status, and the evaluation of these is not always free from personal approach. Unlike this, the finding out of the regularities in the microscopical texture of the skin, which are peculiar to any type of constitution, makes the analysis duly objective.

During the spring clip of 1942 we took samples of skin from sires, wethers and dams of sheep of different constitution at the stock-breeding farm Kara-Kum, Bukhara department, Uzbekistan. The type of constitution was in each separate case determined by an expert karakul sheep-breeder from the staff of the All-Union Institute for Animal Breeding, W. W. Judin.

The sections made were embedded in celloidin-paraffin and stained with haematoxylin-eosin, after which we proceeded to comparative measurements of the thickness of the skin down to the subcutaneous fat tissue. The location of deep and medium-deep hair-bulbs, as well as the cross-section of sebaceous glands were also measured for the two sexes separately.

The results of these measurements are given in divisions of an ocular-micrometer in the table below.

It can be inferred from this table that the thickness of the skin varies according to sex and constitution, and so does the depth of location of the hair-bulbs. In both

Constitution	Sires	Whethers	Dams
Mean thickness of skin			
Delicate	17.5	14.3	12.7
Robust	21.0	17.0	15.3
Coarse	22.0	20.5	15.5
Mean for the three types of constitution	20.0	17.0	14.5
Mean depth of location of hair-bulbs			
Delicate			
Deep-seated bulbs	11	10	7
Medium-deep bulbs	8	6	4
Robust			
Deep-seated bulbs	16	12	11
Medium-deep bulbs	11	9	6
Coarse			
Deep-seated bulbs	16	15	12
Medium-deep bulbs	11	10	6
Mean cross-section of sebaceous glands			
Delicate	0.38	0.44	0.34
Robust	0.57	0.45	0.38
Coarse	0.63	0.46	0.41
Mean for the three types of constitution	0.53	0.45	0.38

cases the differences are especially salient between the two extreme types of constitution, the delicate and the coarse; animals of the delicate and the robust constitution also invariably differ by these characters.

The cross-section of the sebaceous glands increases in a direction from the delicate towards the coarse type of constitution.

The general picture of the histological texture of the skin in a karakul sheep of the delicate type of constitution differs strikingly from that of the robust and coarse sheep. In a sheep belonging to the delicate type the hair-roots are thin, they are located within the corium in different directions, so as to offer a picture of entanglement, and the longitudinal course of the separate roots cannot easily be traced on a section. The bulbs are lodged at different depths, and the subepidermal layer may therefore be found to contain bulbs of different size. As a general rule, in sheep of delicate constitution the hair-roots are less deep-seated than in those of the robust type. There is no regularity in the distribution of sweat-glands, which seems to be connected with the irregular distribution of hair-roots. The glands do not lie in regular packets among the parallel hair-roots, as in the skin of sheep belonging to the coarse type of constitution.

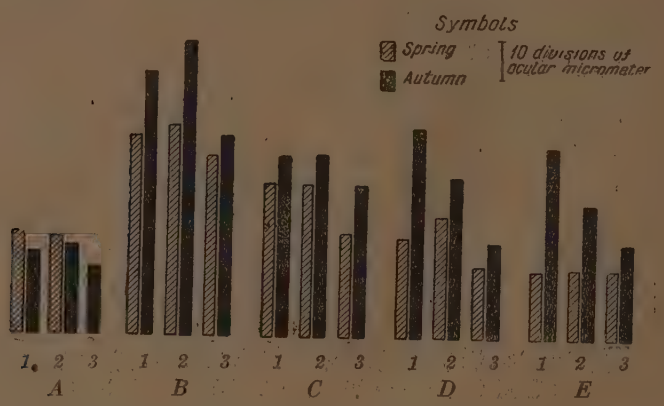
Histologically the structure of the skin of a sheep of robust constitution differs from that of a delicate one in the first line by its being thicker; the hair-roots are seated deeper, they are thicker. The roots of the coarse hairs are located at about the same level, passing through the corium towards the surface of the skin parallel to one another. The sweat-glands are distributed among the hair-roots in packets. There is manifest a definite regularity in the arrangement of the hair-roots, smooth muscles and sweat-glands instead of the «confusion» in the arrangement of the separate elements, which is observed in the skin of sheep belonging to the delicate type of constitution. It should be noted, however, that out of the four skin samples of robust constitution, one was found to display at different areas a texture similar to that of sheep of the delicate constitution. The pedigree of this sheep contains indications to its progeny being poor karakul skin producers.

A question arises as to the connexion between the texture of the skin in adult individuals and the quality of karakul lamb skin in the progeny. In sheep of the

coarse constitution the skin is somewhat thicker than in sheep of the robust constitution. The regularity in the arrangement of sweat-glands and hair-roots is still more salient in all of the four dams examined.

The structure and functional state of sweat-glands in the skin samples taken from all the individuals simultaneously in April 1942 reveal a direct dependence on sex. The most highly differentiated, *i. e.* having the most involute glandular part, are the sweat-glands in ram-sires: in a section they look like minute bunches of grapes, consisting of up to 25—30 vacuoles (corresponding to the openings of the cross-sections of the involute glandular portion).

In dams the sweat-glands are less involute, up to 20 openings can be detected in a section, corresponding to the involutions of the glandular part. The latter is distended, the cells of the gland epithelium are nearly flat, they stain poorly.



1, robust; *2*, coarse; *3*, delicate. *A*, thickness of epidermis; *B*, thickness of skin; *C*, depth of rooting of main hair-bulbs; *D*, cross-section of sebaceous glands; *E*, cross-section of smooth muscles

Together with the adjacent myoepithelial cells the wall of a sweat-gland appears as a thin lamella.

The least differentiated are the sweat-glands in wethers. A section through the involute glandular part may contain from 2 to 6—7 openings. The glands are distended in the shape of elongated sacks, but their walls are not so thin as in dams.

The morphological distinctions in the structure of sweat-glands in the two sexes testify to their different functional conditions, as well. Thus, a profound functional relation seems to exist between the sweat-glands and the sex-glands.

The quantity of pigment present in the epidermis of the karakul sheep in spring is also found to be dependent on sex.

Seasonal Variations. When comparing the skin samples taken from sires in April with those taken in September 1942, we became aware of seasonal variations. Our attention has been first of all attached to the sebaceous glands. The spring samples taken from sire No. 5050 show sebaceous glands of small size, adherent neither to the smooth muscles, nor to the excretory ducts of the sweat-glands. The skin samples taken from the very same sire in autumn show sebaceous glands of a huge size; they are closely connected with the excretory duct of the sweat-gland and with the smooth muscle. In between the lobules of every sebaceous gland one may see the excretory duct of the sweat-gland, as well as the hypertrophied smooth muscle which clings to the whole complex from the one side.

We carried out comparative measurements of the total thickness of the skin, of the thickness of the epidermis, depth of lodging of the hair-bulbs, of the cross-section of sebaceous glands and of the cross-section of the smooth muscles. Measurements were carried out both for spring and autumn samples and for different

types of constitution. The results of the measurements are illustrated by the accompanying graph, from which it may be seen that in autumn the skin becomes thicker in the sheep of all constitutions and especially in those of the robust constitution. The hair-bulbs become deeper-seated. The cross-section of sebaceous glands in rams of the robust constitution increases twice. The smooth muscles are also increased in size. This is especially conspicuous when comparing the increase in the sebaceous glands and in the cross-section of the smooth muscles in rams belonging to the robust constitution.

The epidermis offers a reverse picture: in September it becomes thinner than in May, and the pigment cells vanish from it almost entirely. Unfortunately, among our autumn samples there were none from dams and wethers, and we could therefore not find out whether their skin texture is subject to seasonal variations.

In the practice of sheep-breeding it is a well-known fact that the quality of the wool-fibre depends upon its being greased with products of sweat and sebaceous glands. It goes without saying that the quality of wool is influenced by the thickness of the skin, as well.

From the same graph it is evident that the growth of the sebaceous glands and the increase in the thickness of the skin is especially pronounced in rams belonging to the robust type of constitution. A further investigation of seasonal variations in the skin of dams and wethers seems therefore highly desirable.

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ECOLOGY

ON LIMITS OF LIFE AT NEGATIVE TEMPERATURES

By S. A. ZERNOV, Member of the Academy, and O. I. SCHMALHAUSEN

It is usually assumed that under natural conditions the temperature of liquid water inhabited by living organisms is never below—3.3° C. This was the temperature found in the Atlantic Ocean near the eastern coast of North America, east of Nova Scotia. No one, however, has noticed the fact that in our latitudes the temperature of the water in the salt lakes drops much below —3.3° C in winter.

In the course of our observations on the types of plankton inhabiting the lakes of the Borovoe reserve (Akmolinsk district of the Kazakh SSR), carried on throughout the year, we found a live and mobile population (qualitatively a very poor one, it is true) in the salt lakes Ulkonsor and Balpash, at a temperature of —5 and —7.75° C.

Our main work embraced seventeen lakes of the Reserve. According to unpublished data by E. V. Paley, these lakes may be classed into four groups according to their salinity. The lakes Ulkonsor and Balpash belong to the fourth group, that of highly mineralized chloride-sulphate-sodium-magnesium steppe lakes. These lakes for a number of years have a constant chemical composition, being liable, however, to considerable annual and seasonal variations in the concentration of these salts.

On March 11th, 1943, O. I. Schmalhausen and D. F. Bernik took a sample of plankton from lake Ulkonsor. The lake was then covered with an ice sheet 109 cm thick. The bottom layers of ice proved to be loose, very soft and saturated with water. The depth at the place of sampling equaled 145 cm from the ice surface; there was consequently no more than 36 cm of free water under the ice. The water exhaled a pronounced odour of hydrogen sulphide. The temperature of the water was—5°C, the minimum air temperature, —11.2°C. The sample of plankton taken was found to contain thirteen species of algae, only one of which, possessing four flagelli and present in considerable amounts, appeared to be mobile. This form probably belongs to the genus *Pyramimonas* Schmarda, family *Polyblepharidaceae*. Its shape is much similar to that of *Pyramimonas tethrarhynchus* Schd., being likewise piriform and bearing 4 longitudinal furrows. Owing to a number of internal characters, however, it cannot be referred to this species. Professor N. N. Voronikhin who is now studying the algal flora of the water-reservoirs of the Borovoe reserve, has undertaken to define the systematic position of this form more precisely. According to his information, among the plankton sampled from lake Ulkonsor on March 11th, 1943, there were various algae, viz. *Oscillatoria*, *Nodularia*, *Gloeotila*, *Botryococcus*, which have not lost their colour and were probably also alive, like the swimming *Pyramimonas*.

Pyramimonas itself thrives in aquaria when kept in a warm room. O. I. Schmalhausen carried out with it the following observations. On March 18th the aquaria were heated, and the thermal limit of life for *Pyramimonas* was found to be at about 29°C. In the aquaria where the temperature was raised to 30.4° and 32.6°,

all the *Pyramimonas* were found to be dead. At 29° part of them were swimming, while another part lay immobile. On March 19th the minimum air temperature was —11.2°C. The aquaria were transferred to a colder room, where the water in them soon turned into a brine of a soft consistency; the temperature was —5.2°. The *Pyramimonas* were still alive and swimming. On March 20th the air temperature went down to—19.9°; the aquaria transferred to a cold room showed a temperature of—15°, soft ice was found to be formed in them. But the water taken from this ice with a pipette was still found to contain swimming *Pyramimonas*. Finally, on March 23rd, when the minimum air temperature dropped as low as—27.5°, and solid ice formed in the aquaria, a portion of it melted in a room was found again to contain swimming *Pyramimonas*. We have no information as to the state of the *Pyramimonas* when they were in the ice. At all events, the perfect vitality of the *Pyramimonas* which showed no signs of anabiosis in a brine cooled to —5.2° and in soft ice at—15° is beyond any doubt. We feel sure that at the period between the 11th and 23rd of March, when the water temperature in lake Ulkonsor might have dropped below—5°, the *Pyramimonas* were alive and swimming there. And this seems the more probable as the plankton sample taken from the salt lake Balpash at the same period contained water cooled to —7.75°, and there were live swimming flagellate *Dunaliella* in it. Under experimental conditions similar to those observed in our experiments with *Pyramimonas*, *Dunaliella* were found to swim at— 15° in soft ice.

The upper thermal limit of life for *Dunaliella* proved to be at+42°C. In lake Balpash N. N. Voronikhin observed, along with *Dunaliella*, also a small quantity of *Ulothrix* (green algae of the order *Ulotrichales*) with intact chromatophores, and *Diatomaceae* of the type of *Synedra*, apparently also alive. Lake Balpash shows a higher concentration of salt than lake Ulkonsor. At the day of sampling the amount of Cl in the water of Ulkonsor was 4.765 g per 100 cm^3, while in lake Balpash it was 9.165 g. Accordingly, the ice-layer over lake Balpash was very thin, 33 cm thick only. The ice was very soft, and there was 37 cm of water below it. The summer plankton in the two lakes varies widely.

Conclusions. We have found that mobile flagellate *Pyramimonas* and *Dunaliella*, as well as a number of other algae, survive the winter in salt lakes in a water cooled down to —5 and—7.75°C, probably even below, without displaying any signs of anabiosis. Up to the present the negative temperature limit of life in unfrozen water has been put at—3.3°C in a certain part of the Atlantic Ocean. Under experimental conditions *Pyramimonas* and *Dunaliella* were found to survive and swim in a drop of water taken from soft ice formed from the water of a salt lake and cooled to—15°C. The limit of positive temperatures for the same organisms was found to lie at+29 for *Pyramimonas* and +42°C for *Dunaliella*.

These data may serve as valuable supplementary material for the conclusions which have been drawn by S. A. Zernov and his co-workers in their paper on the hibernation of aquatic organisms in ice and frozen soil (1).

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PHYSIOLOGY

ON LOCATION OF GRAVITY CENTRE IN MAN

By A. M. DAMIR

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1. The locating of the centre of gravity Z in the human body is a most ancient problem, but no definite solution of it has been found as yet. Investigations on this subject may be traced back up to the XVII century ([1–9]). Within recent years N. Bernstein ([10]) has developed a method for determining Z, which from the preliminary information (its full description has as yet not been published) appears to be essentially new.

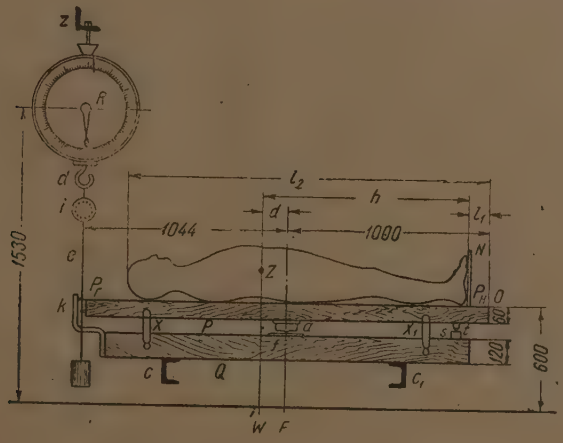
Among the available designs only that devised by Cotton ([9]) gave the apparatus intended for determining Z the adequate sensitivity for the solution of problems that call for the creation of such apparatus. Unfortunately, Cotton, having taken a long stride towards the attainment of the necessary sensitivity, has not at the same time got rid of such systematical errors as the inaccurate estimation of the length of a human body in the lying attitude, the hanging down of the soles, the difficulty of bringing the patient into identical position in repeating the determinations of Z. Attempts to eliminate these drawbacks went to decrease the sensitivity of the apparatus.

In the design proposed here the author tries to remove the sources of systematical errors without impairing the sensitivity of the apparatus.

2. Description of Apparatus. Base Q made of oak-planks. Breadth of Q 40 cm, thickness of Q 12 cm (see figure). To prevent Q from sagging a cross-plank 3 cm thick supports Q in the centre. Q rests upon two T-beams C and C_1, embedded into the wall, Q being tightly bolted to them. Platform P is a beechen board, 200 cm $\times$ 50 cm $\times 2^1/_2$ cm. Side planks $6 \times 2^1/_2$ cm made also of beech counteract the sagging of P. Fulcrum F is provided by two steel prisms f which rest with their «knife edges» on a steel base a. The line of F cuts P in two, and halves P_h and P_f are described as head-half and foot-half, respectively. The steel bolt K fitted into P_h has a conical notch below, owing to which the thin steel wire-rope e, connecting K with a hook d of a circular balance R, keeps the point of fastening to P_h at a constant horizontal distance $L = 104.4$ cm from F. The foot-half P_f is provided with a movable support N fixed by a bolt which can be freely shifted along a slit 35 cm long, cut in P_f. In order to measure the length of the body accurately, steel rules 200 cm long divided into centimeters and millimeters, the line «1 m» coinciding with F, are fastened on both sides of P along the upper surface of the boarder lath. The length of the body is measured by a wooden lath which is shifted along the corresponding divisions of the rule to bring it into intimate contact (but without pressure) with the sinciput and with N. Bercle's balance R for a limit load of 10 kg, accuracy of measurement 10 g, is suspended on a T-beam z which is fitted into the same wall (main wall of the building). This set-up eliminates the vibrations of the floor and ensures exact measurements. The tap-line i, around which the wire-rope e is wound, permits the distance K—d

to be changed at will (within the limits of displacement of the hook d, *i. e.* within 4 cm); the wire-rope e can therefore always support P in a horizontal attitude under the load of a human body of any weight. The arrests x and x_1 are wooden laths fastened to Q by means of collars. A turn of a clock-hand through 90° brings them out of horizontal into a vertical position. In order to arrest P we have to lower P_h and to turn x_1; then x is turned, in which for smoothness of run two ball bearings 4 cm in diameter are cut in. With x and x_1 in the raised position P is secured from a lateral shift by cogs with which x and x_1 are provided; when x and x_1 are in the lowered position, P is fixed by brass cylinders s 4 cm in height, 2.4 cm in inner diameter, which are mounted in Q; above them conical pins t are cut into the lower surface of P_f, which enter into the sockets of s when P_f is lowered.

3. Determination of Z. The patient, wrapt into a sheet of khown weight, is weighed on Block's decimal balance. Let W be the weight of the body. N is preliminarily adjusted on P at such a distance l_1 from the end of P_f as to



weigh down P_h when P is fully loaded. After N is adjusted, P is poised by adding load to its raised end. Now both ends of P are arrested, first P_f and then P_h. The patient lies down upon P_h with slightly bent knees, and bringing his soles in contact with N, stretches out to full length in such a way that the straight line connecting the corner of the eye with the ear's opening be perpendicular to P. The height (length) H of the patient is measured in centimetres, as mentioned above. First the arrest x and then x_1 are lowered. P is afterwards brought in a strictly horizontal attitude by shortening the length $K-d$ (of wire-rope e) by means of tape-line i. Finally, two extreme indications of a continuously oscillating hand are read on the balance dial and their mean, w, is taken. Under these conditions the distance h of Z from the soles is given in per cent of the body length by the formula

$$h = 100\,(100 - l_1 + d)/H$$

where $d = 104{\cdot}4\ w/W$.

4. Accuracy and Sensitivity of the Apparatus. To make sure that our device operates accurately and gives reliable results, we arranged control tests in which it was loaded with inert heavy masses. It was found that in the first place the determinations of the centre of gravity of these masses invariably coincided with the results obtained by other methods (experimentally or geometrically) and, secondly, that the response of the hand R to an additional load of $n \times 10$ g applied to point K of P was always to shift exactly over n divisions. It should be emphasized that the apparatus

cannot possibly be controlled by a human body on account of the extreme sensitivity of the whole system. When a patient is being measured, the hand of the balance is in constant motion. Some of its oscillations (*viz.*, the wider and rarer ones) are due to respiration; their range is usually 50 g, but sometimes it extends over 500 g. They may be accounted for by a periodical displacement of the diaphragm whose movements involve such heavy organs as the liver and the spleen. At every inspiration Z is displaced towards the feet. The narrow and frequent oscillations are connected with the activity of the heart: at every systolic propulsion of blood, Z is displaced towards the head, whereas the diastole displaces it towards the feet, the range of oscillation being from 5 to 10 g. Such a sensitivity is quite sufficient for solving the set of problems which are confronting us.

5. First Results. In spite of the above-mentioned mobility of the centre of gravity in man, its displacement is confined within narrow limits which are never broken. In the human organism there is a sphere S, 7 per cent of body length in diameter (which makes 10 cm on the average), within which Z is always contained, whatever the physiological (pregnancy) or pathological (oedema) state of the organism. Inside this sphere is a smaller sphere s, 2 per cent of body length in diameter (3 cm on the average), which comprises Z in all healthy human beings. These two spheres, S and s, are probably concentrical. Their common centre in males is the point $h = 0.572H$; in the case of females, $h = 0.564\,H$. So narrow a range of variation of Z suggests the existence of a constant of human organism. Every displacement of Z is due to a shift of masses in the organism. Z is displaced by respiration, pulse, after standing, walking, running exercise. The position of Z is likewise affected by various pathological conditions. Therefore it is very important to know the nature and the value of the shifting mass. If considered apart from the living organism, the displacement of Z means nothing, but if the main properties of the organism are taken into account, the displacement of Z gives an idea of the displacement of the centre of gravity of the mass shifted within an organism, of its weight and dimensions, and of the parts of the organisms from which it is displaced and where it is accumulated. The first circle of problems is naturally linked with bleeding, in which case the mass of the liquid lost needs not be found from the displacement of Z, but is given directly.

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ENDOCRINOLOGY

DEVELOPMENT OF THYROID IN *PHALACROCORAX CARBO*

By A. A. WOITKEWITSCH

(Communicated by L. A. Orbeli, Member of the Academy, 24. XII. 1943)

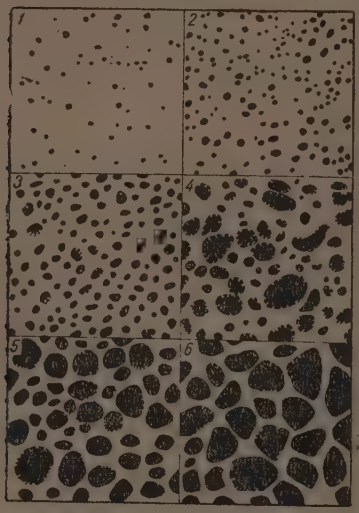
Experiments involving extirpation of endocrine organs made it possible to establish that the development of vertebrates is determined by the hormonal activity. However, the nature of the hormonal determination cannot be understood correctly, unless the behaviour of the endocrine organs is observed throughout the process of development of the organism.

Extirpation of the thyroids in young birds results in a lagging of their general development. Thyroidectomized birds show a smaller body size as compared with normal birds; their pterylae are mostly lacking a feather covering. The effect of thyroidectomy in young birds is the more pronounced, the earlier the date of operation. The results of the experiments permit to speak in a general form of a relation existing between the processes of growth and differentiation and the thyroid hormone. The development of the organism is characterized by a certain periodism, and the hormonal agents seem to play no insignificant part in the determination of this periodism. Our khowledge of the morphogenetic activity of the thyroid hormone will be advanced considerably if the results of the experiments are reinforced by data on the state of the gland, secured at various periods of the organism's development.

The studies devoted to the development of the thyroid in birds, and in the rest of vertebrates, too, are few in number. It is in chicks and pigeons that the formation of the thyroid was traced in most detail. The variations in the structure and function of the thyroid observed in those two species were used up to find out the rôle of the thyroid hormone in determining certain peculiarities of the morphogenetic processes. The necessity of widening the range of observations on the behaviour of the thyroid and of the rest of endocrine gland scarcely needs to be stressed. The study of the regularities underlying the development of glands of internal secretion in various forms differing as to their ontogenesis is important in another juncture, too. Namely, it may furnish information for a better knowledge of the nature of taxonomic distinctive features formed in the course of historical development in the hormonal determination of the process of morphogenesis. At this angle of view the method of comparative investigation assumes a particular importance.

All that has been said above induced us to trace the development of the thyroid in a wild form for which the regularities of postembryonic growth had previously been studied in detail. The necessary material was collected in a colony of cormorants settled at the territory of the Astrakhan reserve. We had at our disposal 188 young birds of various age, males and females, and 14 two-year-old birds. The young taken from their nests were, as a rule, autopsied after a number of days multiple of five. Young birds of intermediate stages were also examined.

As the initial stage embryos 5 days before hatching were considered; the second stage was represented by young just hatched, the third by young birds 5 days old, *etc.* The autopsies were practised within one month and a half, *i. e.* when the growth of the birds under observation was not yet complete. Adult, sex-mature individuals were also taken for comparison. In each case both lobes of the thyroid were extirpated; the glands were weighed and directly fixed with Zenker's fluid with formalin. The glands were embedded in paraffin and cut into sections 7—8 μ thick. Part of the sections from either lobe were stained with haematoxylin and eosin, another part was stained after Mallory, the nuclei being stained with azocarmin. Along with the examination of the microscopic structure of the organs, we also measured with the aid of an ocular micrometer the height of the epithelium and the inner diameter of the follicles (50 measurements were made for each lobe).



Equal areas of sections made through thyroids of individuals of different age (follicle colloid, solid black): *1*, moment of hatching; *2*, 5 days; *3*, 10 days; *4*, 15 days; *5*, 30 days upon hatching; *6*, adult bird. Drawings made at equal magnification

As well known, the results of such measurements are the most objective indices in judging of the function of a definite organ. With a functioning gland the quantity characterizing the intensity of excretion of active principles into the humoral medium of the organism is in a direct dependence on the height of epithelium and in an inverse, on the amount of the colloid substance preserved in the follicles. The correlation between the epithelial portion and the colloid in a forming or functioning gland becomes quite demonstrative when comparing the drawings made with the aid of Abbe's camera lucida of equal areas of sections prepared with different glands. By this method the dynamics of age-variations taking place in the thyroid apparatus can easily be traced (see figure). We have also found the relative weight of the thyroids in birds of different age.

In each set the average figures were calculated for all indices.

Along with the development of the birds the weight of the thyroid changes synchronously with the total body weight. The absolute weight of the organ gradually increases during the first 30 days of the bird's life, after which it is somewhat reduced. The weight of the thyroid in birds that have completed their growth differs but little from that of adult birds. The thyroid attains its maximum relative weight in 10—15-day-old birds, *i. e.* at a period when the rate of general growth begins to decrease and the processes of differentiation of the organism become more intense.

In the process of development the microstructure of the thyroid undergoes essential alterations. The embryonic thyroid tissue is made up of epithelial bands, the cell structure bears no signs of secretion, the follicles are lacking. By the moment of hatching small individual follicles are observable; in the cavities of the follicles poorly staining colloids are seen to be deposited.

During the subsequent 10 days the differentiation of the follicular structure becomes more intense. At this period we cannot speak yet of a function of the organ, at any rate the level of its hormonal activity is no high one. It is in 10-day-old birds that the thyroid shows a maximum number of follicles of a rather small size.

In the subsequent developmental stages the changes in the microstructure consist largely in an increase of the height of the follicular epithelium and in an

Weight and Microstructure of Thyroid in *Phalacrocorax carbo* in the Course of Development

Age in days	Body weight of bird in g	Thyroid			
		Weight (both lobes)		Height of epithelium in μ	Diameter of follicles in μ
		in mg	in %		
—5	5	0.6	0.0111	5.22	0
Hatching	41	6.6	0.0110	5.46	7.39
5	234	21.5	0.0092	6.02	16.90
10	551	73.5	0.0115	6.80	23.85
15	1003	124.2	0.0123	8.94	33.74
20	1463	149.4	0.0102	8.30	33.43
25	1702	180.3	0.0106	7.96	34.80
30	1880	217.8	0.0116	7.58	40.39
35	1945	202.1	0.0104	7.51	39.79
40	2040	192.3	0.0094	7.75	39.18
45	2133	153.6	0.0072	7.21	41.11
2 years ♀	2147	131.2	0.0061	8.26	41.00
2 years ♂	2263	149.5	0.0066	7.38	36.24

accumulation of the colloidal substance in the growing follicles. Vacuolization of the protoplasm in the cells of epithelium and liquefaction of the colloid (which point to a hypersecretion of the gland) set in after the tenth day. The thyroid of a 15-day-old bird shows, as compared to the preceding period, signs of a maximum activity, which remains at about the same level during ten days. After a month upon hatching the activity of the gland seems to be less intense: the quantity of homogeneous colloid becomes larger, the height of epithelium decreases, the resorption vacuolae in the follicles become sparse. Towards the end of the growth-process, the gland shows a picture typical of that of a sex-mature bird.

A comparison of the figures referring to the weight and microstructure of the thyroid gives us ground to infer that the development of this organ can be subdivided into three phases: the first phase comprises the first 10 days following hatching, when an intense differentiation of the structural elements takes place and the secretory activity of the organ sets in. The second phase lasts until the birds become 30 days old; this period is characterized by a relatively high function of the gland with typical signs of hypersecretion. The third phase embraces the subsequent developmental period up to the completion of growth; it is characterized by a lowered function of the gland, the structure of which gradually assumes such characters as are typical of an adult bird.

It should be pointed out that the thyroids of adult birds display no sex differences, either in dimensions or structure. The relative weight of the thyroids of sex-mature individuals is about a half that of young birds at the period of growth. The size of the organ is subject to individual variation; not infrequently the left half of the organ is larger than the right one (twice or thrice by weight).

The data here discussed permit to conclude that there is a parallelism between the variations in the development of the thyroid and the periodicity of the general growth of *Phalacrocorax carbo*. The process of the most intense growth at late stages of embryogenesis during the first period upon hatching is attended by no correspondingly high function of the thyroid. On the contrary, it is just at this period that the activity of the organ is particularly low, on account of the formation of the secretory apparatus. The beginning of the hyperfunction of the thyroid corresponds to a decrease in the rate of growth. The phase of the high activity of the gland corresponds to the period of an intense development of the plumage. During the second month of the bird's life the rate of general growth is reduced considerably, the differentiation of the organism comes to an end. At this period the variations that occur in the structure of the thyroid are typical of the reduced function of the organ. The thyroids of young (1.5-month-old) and of adult sex-mature individuals scarcely differ in any of the characters analysed.

On the ground of the data secured we are led to conclude that the hormone of the thyroid does not play an equivalent rôle in the process of growth and in that of differentiation of the cormorant. The growth of the organism proceeds with maximum intensity just at the period when the level of hormonal activity is rather low. A certain concentration of the thyroid hormone in the humoral medium seems to be necessary in order that the intensity of metabolism be maintained at a definite level during the different phases of general growth. The results of thyroidectomy practised with young cormorants also support this conclusion: the extirpation of the thyroid, even if practised at a very young age, brings about no considerable lagging behind in the general growth of the birds as compared to controls.

The processes of the organism's differentiation, one of the particular cases of which is presented by the development of the plumage, go on under conditions of a high activity of the thyroid. As a good illustration may once more serve the results of experiments on thyroidectomized birds: the development of plumage in them suffers strong inhibition, if there is any development at all. Even after having attained a rather advanced age, the young birds still display characters of altrical condition.

In concluding it should be pointed out that at the period of the highest activity of the thyroid its hyperfunctional changes in the cormorant are less pronounced than in the rest of birds investigated by us at a corresponding period of development. The height of epithelium varies within a narrow range. Even at a period of the most intense determination of morphogenetic processes due to the thyroid hormone, the gland preserves a considerable reserve of active principles connected with the colloidal substance. The liquefaction of the colloid, which finds its morphological expression in vacuolization, involves but a small boundary zone of the follicle's cavity.

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